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ECOLOGICAL VALUE, CULTIVATION, UTILIZATION AND COMMERCIALIZATION OF *ALOE VERA* IN GREECE

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ABSTRACT

Aloe vera seems to have an essential role over millennia in several cultures, as well as in Greek. Nowadays it is a fact that Greece, because of the economic crisis, focused on the cultivation of alternative plants including *Aloe*. This cultivation attracts the farmers' interest both for its good adaptability to the local climate and for its beneficial properties. According to the literature, they can harvest 7,000 kg of leaves containing about 70-80% gel per acre. Also, it is noteworthy that the main purpose of the cultivation of this species, is the leaves' processing in order to obtain its beneficial properties for skin, health, weight loss etc. In addition, as far as the domestic commercialization and market demand of *Aloe vera* are concerned, it is observed that they are still in an embryonic stage, and are in need of enrichment with direct supply chains with the pharmaceutical and cosmetic industries that will supply with *Aloe's* gel their production lines. The present review focuses on the current state of the *Aloe*'s cultivation, utilization and commercialization in Greece, so it can be used as a baseline information for further research.

Keywords: *Aloe vera*; cultivation; ecological value; utilization; SWOT analysis; sustainability; Greece.
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INTRODUCTION

During the last decade, an increasing trend to establish new alternative crops has appeared in Greece (Aegean islands, in Peloponnesus, and the south part of the Greek mainland) (Figure 1, 2) (Vakalounakis *et al.* 2015). One of the most important crops is *Aloe vera*, a perennial plant with high ecological and economic value. It is particularly widespread for its constructive health, beauty, medical and skin care properties in several cultures (Greece, Egypt, India, Mexico, Japan, and China) for millennia (Marshall 1990).

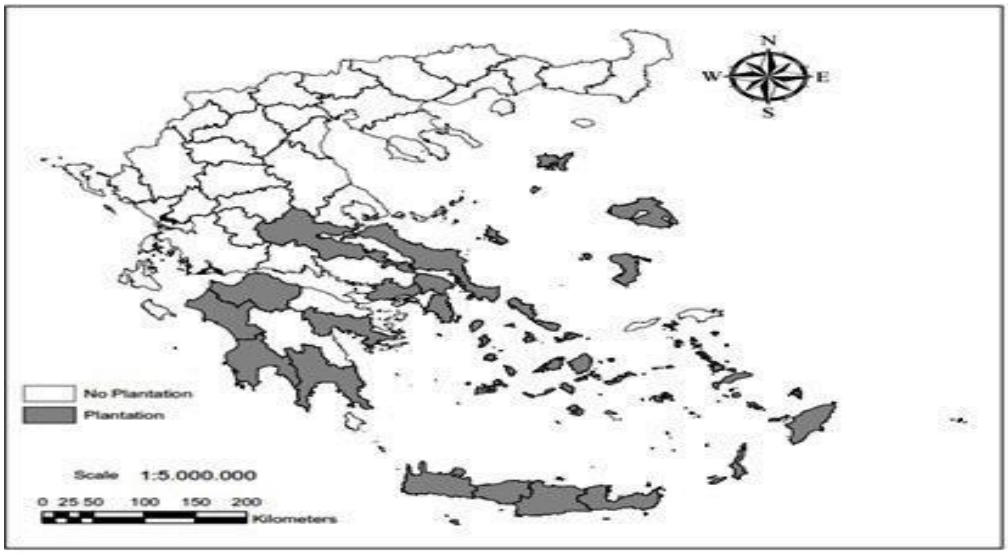

Figure 1. *Aloe vera* crop in Greece. Source: Prepared by the authors using ArcGIS 10.2.2.

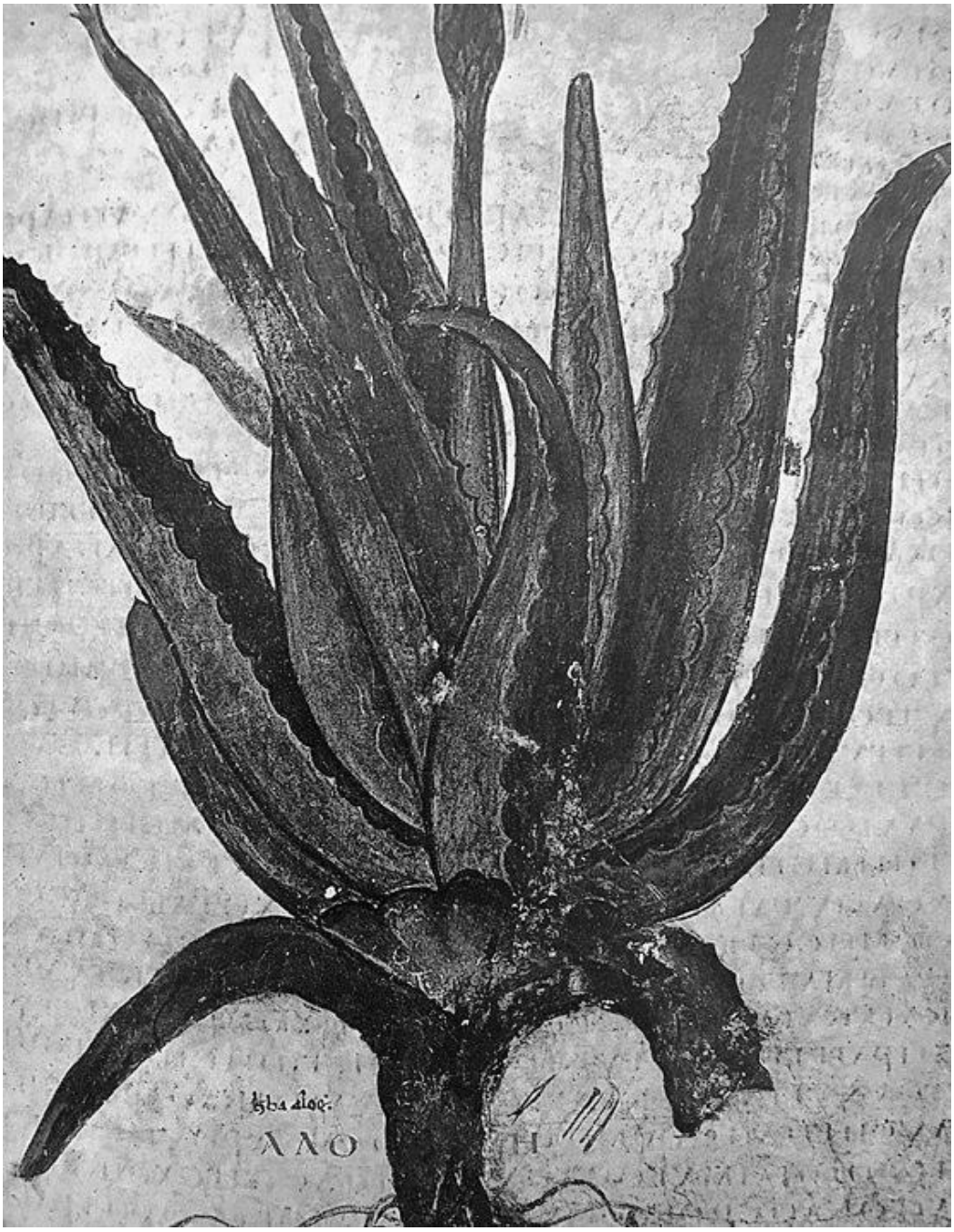

Figure 2. Depiction of Aloe, labeled in Greek Aloë from the Juliana Anicia Codex. Source: Http1.

As far as the botanical classification is concerned, the genus *Aloe* belongs to the Xanthorrhoeaceae family (according to the Euro+MedPlantBase) or to Aloaceae family (according to USDA Natural Resources Conservation Service) and includes more than 450 species, which are native to Africa and the Mediterranean region. It is a fact that, the botanical classification of the species is quite complicated due to the intersections between them, both in their cultivate and wild form (Euro+Med 2006; The Plant List 2013; EuroPlusMed 2018; USDA 2018). The name *Aloe vera* originates from the Arabic word "Alloeh" meaning "shining bitter substance," while "vera" in Latin means "true" (Hatano *et al.* 2005; Surjushe *et al.* 2008; Eshun and He 2010). *Aloe vera* (Aloe the true) and *A. barbadensis Miller*, are the most common names which were used until recently by the experts. However, in recent years, *Aloe vera* has been established as the most accurate name (Figure 3) (Reynolds 2004).

Figure 3. *Aloe vera* in Greece. Source: Photo taken by the author A. Solomou.

Aloe vera crop is one of the most promising alternative crops that have been recently established in Greece, particularly during the current economic crisis. It is noteworthy that it remains to enrich mankind with new medicines and it can utilize poor agro ecosystems and therefore, can favour rural development in marginal areas (Liontakis and Tzouramani 2016). Despite the wide research on the utilization of the *Aloe vera* (Ahlawat and Khatkar 2011; Sahu *et al*. 2013; Atlaw 2018), only few researches exist concerning the cultivation practices and commercialization of this plant in Greece. Hence, our research focused on an extended review survey in order to give the first comprehensive information about cultivation, utilization and, commercialization of *Aloe vera* crop in Greece and generally in the Mediterranean area. It is remarkable that this contribution will be a valuable tool to botanists, foresters, wildlife biologists, agriculturists, climatologists, horticulturists, the general public.

MATERIALS AND METHODS

Literature review is a thorough fathom into the already existing knowledge with regard to a topic selected by researchers (Botelho *et al*. 2011). The literature search relevant to the cultivation, utilization and commercialization of *Aloe vera* in Greece was decided to take into consideration the period of the past 30 years with particular emphasis in recent literature (from year 1986 to 2018). The information was obtained from the main online scientific sites including Science Direct, SciFinder, PubMed, Google Scholar and Scopus. Searches were also undertaken in the Institute of Mediterranean and Forest Ecosystems, and University of Thessaly library, dissertation and thesis search engines like ProQuest, Open-thesis and National Documentation Centre. The keywords used in the search included "cultivation", "utilization", "commercialization" and "*Aloe vera*" (Figure 4). The literature sources included papers published in international journals, books, thesis and websites. Full papers were downloaded when it was possible. In cases when it was not possible to download full papers, titles of those papers were googled and downloaded from other publication databases such as Research Gate and Academia.edu.

Figure 4. Word Cloud of key-words that it has been used in the scientific sites.

Source: Prepared by the authors using Word Cloud program (Http2).

RESULTS AND DISCUSSION

Morphology and anatomy: The group of species to which *Aloe vera* belongs, is distinguished from related species by the fact that it forms a simple or slightly branched inflorescence, while the plants produce many leaves. It is a perennial slow growing succulent, up to 160 cm height. It does not form a central stem or if it is formed it has a small length that reaches up to 30 cm.

The leaves are 16-20 in number, they are slightly upright and form a dense rosette at the base, which opens upwards. They are thick and fleshy with wide and lanceolate shape, toothed in the circumference due to the existence of white thorns about 2 mm long (Davis 1997). They consist of 3 layers: The inner part called gel, which consists of 99 % water and 1 % glycomanans, amino acids, lipids, sterols and vitamins, the middle layer called latex, which is a bitter yellow mass containing anthraquinones and glucosides, the outer layer is called crust and has a protective function as it synthesizes carbohydrates and proteins (Tyler 1993). Their outer bark is hard and waxy and contains a gel-like liquid that allows the storage of water and nutrients and contributes to the survival of the plant during periods of drought. At a young age, they have a light green color that changes to deep green as they are ripened, while some varieties have white spots on the surface of the lamellae. They germinate directly from the base of the plant, stalkless and cyclically, and may exceed 50 cm in length, and 8-10 cm in width, while their thickness is about 5 cm.

The flowers grow from the center of the plant in the form of a simple or branched bristle inflorescence carried on the end of a flowering stem of 60-90 cm long. The flowers are hermaphrodite, trimeric, up to 3 cm long, swollen in the ovary area with shades ranging from yellow as orange or red. The fruit is a capsule, multilayered, with lots of seeds, and it carries partitions along the ovarian spaces that are separated during maturation and the seeds are released. The seeds are dark brown in color, and 7 mm in length (Figure 5) (Davis 1997).

Crop ecology and cultivation practices: Although the root system of the plant is quite superficial, it can cope well enough in drought conditions, in case of proper installation. As a Crassulacean Acid Metabolism (CAM) plant, it can photosynthesize during the day by keeping the stomata closed, thus limiting water losses through perspiration. This feature combined with thick skin and fleshy leaves and stems make it drought tolerant and ideal for growing in dry conditions.

The process of pollination in aloe is accomplished by both insects and birds. In the areas of Africa where it is indigenous, the flowering and fruit production of the plant becomes normal. However, in many areas where aloe is cultivated and the conditions are not conducive to the formation of fertile pollen, combined with self-compatibility, it results in fruitless and seedless production (Kluge *et al.* 1979; Greek Ministry of Rural Development and Food 2011; Karkala and Bhushan 2014).

It is a plant susceptible to strong air streams that can break the shoots and leaves. Aloe generally resists high summer temperatures, although it may cause a slight slowdown in growth if they remain high for a long time. It is a plant with great adaptability and that is the reason that we encounter it in various lengths and widths of the earth. Also, it is important to mention that the growth rate of the plant varies depending on temperature, rainfall and photoperiod. It takes a period of 4-5 years to reach maturity and remains productive for 3-9 years. Over the life of 12 years it can produce more than 80 leaves (Figure 6) (Greek Ministry of Rural Development and Food 2011; Karkala and Bhushan 2014).

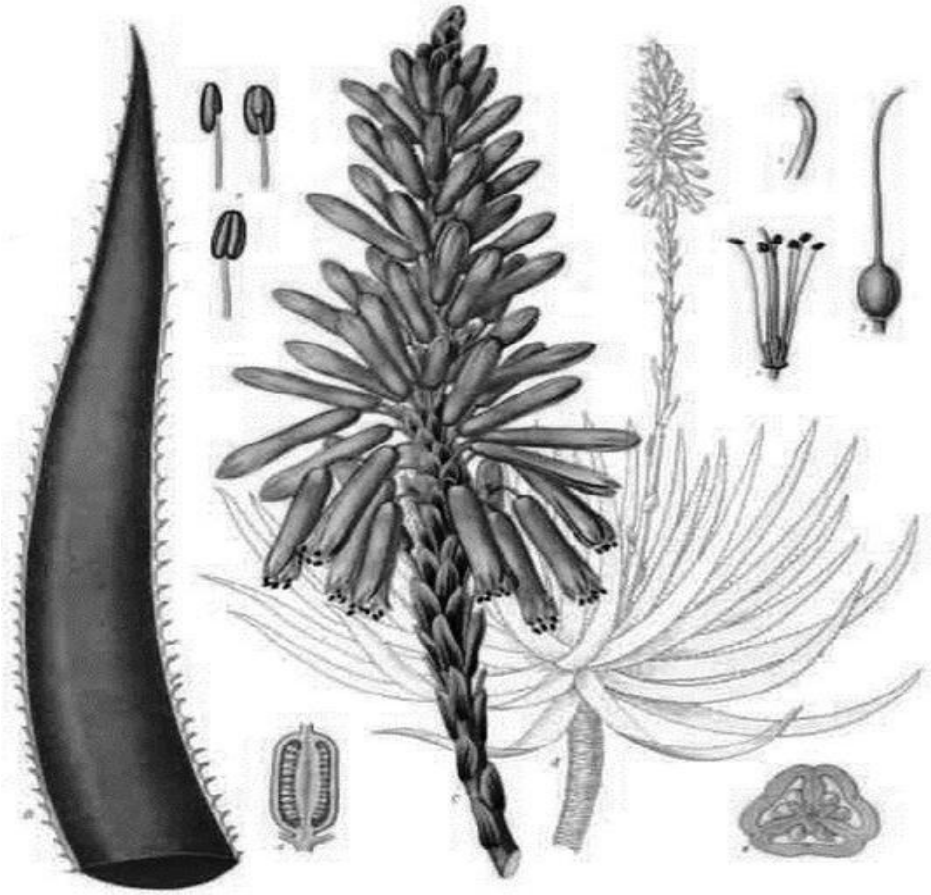

Figure 5. Morphological and anatomical traits of *Aloe* sp. Source: Http3.

Figure 6. *Aloe vera* crop in Greece. Source: Photo taken by the author A. Solomou.

Field preparation and planting: *Aloe vera* plants are planted in March or September, 1200-1300 plants / acre, at a distance of 75 cm x 75 cm and at a depth of 15-20 cm. The cultivation reaches the full yield in the 4th year. Then we can harvest from each plant at least 4 leaves, three to four times a year and 13,000 leaves per acre. Each leaf weights 400 - 800 grams, one acre yields 7,000 kg of leaves containing about 70-80% gel (Louis Aloe 2018).

Climate and soils: *Aloe vera* can be cultivated in a wide range of climatic conditions, preferring well drained, sandy or loamy soils. It can be grown on rocky dry and nutritious soil, however it is recommended to be cultivated in rich and fertile soils to achieve maximum yields. Soils with a slightly alkaline reaction are more suitable for soil reaction, whereas if it is cultivated on alkaline soils (pH ≥8), the growth of the plant will be limited and slow (Louis Aloe 2018). In addition, it is not very resistant to low temperatures, however it can it withstand low temperatures up to -3°C and deal with only minor damage (Grindlay and Reynolds, 1986). According to the International Aloe Science Council (IASC), the ideal temperature for plant growth is between 20-25°C, while it is recommended to avoid sudden temperature changes between day and night. It can grow in climates ranging from temperate to tropical and does not withstand low temperatures due to its high water content (95%). It is a photopphile plant, but can also be cultivated in slightly shady places. During winter, the subtropical areas enter a lethargic state, limiting their water needs to a great extent.

Soil preparation: Prior to planting, a scraping of the soil at a small depth (20-30 cm) occurs, given the plant's root system. 1-2 milling and leveling of the soil take place afterwards. Then mounds can be created with dimensions that vary depending on the irrigation system installed in the plantation, the slope of the soil etc. (Smith 2003).

Fertilization - Irrigation: Usually no chemical fertilizers are used, as the crop of Aloe is preferred to be biological. Particular attention should be paid to nitrogen fertilization to ensure optimal yields, it is recommended to apply 5 kg of nitrogen per acre. Furthermore, quite often it is used, manure which improves the structure and composition of the soil, ranging from 1-1.5 tonnes per acre. The plant is resistant to drought conditions however the possibility of irrigation greatly improves final yields. Irrigation is necessary immediately after transplantation, followed by 2-3 irrigations to ensure good planting. Usually 4-6 irrigations per year are applied depending on the growing area and prevailing conditions, while an additional slight irrigation can be applied after harvesting the leaves, in relation to the availability of water (Ahmed 2011).

Herbaceous plants – Pests and diseases control: Throughout the cultivation the soil should be maintained without herbaceous plants (harmful). Every year, 2-3 cuts of herbaceous plants must take place, followed by light carvings, in order to promote plant growth and offshoot production. The first carving should be done within the first month of planting. Moreover, regular checks out of the cultivation should also be carried out to remove any diseased, non-productive plants, while dried floral stems should be carried out. Plant protection of plants is not a particular problem as the hard and thick skin of the leaves is an important natural one defense for the plant. Problems can be occurred by the bacterial genus Erwinia (*Erwinia chrysanthemi*) that cause leaves' rot, by the fungi genus Alternaria (*Alternaria alternata*) and *Fusarium solani*, as well as frosts, strong winds and rodents (Smith 2003).

UTILIZATION OF *ALOE VERA*

Dermatological Use and Antiseptic Action: *Aloe vera* has the potential to penetrate deeper into the body tissues in about 7 layers. It has six antiseptic agents (lupeol, salicylic acid, urea nitrogen, cinnamonicacid, phenols, and sulfur), which have the potential to kill bacteria, viruses, and fungi. In addition, it stimulates the growth of new tissues and it has a calming effect on the nervous system as it cleans and detoxifies the body and normalizes body metabolism (Kambizi and Afolayan 2008; Feily and Namazi 2009; Titus 2012). Also, it is a remarkable fact that the *Aloe vera* increases the collagen content of the granulation tissue as well as its degree of crosslinking as a result in restoration of tissue integrity (Chithra *et al*. 1998).

Antibacterial action: Alloin and aloe-emodin have potent antibacterial and antiviral activity as they are used as laxatives, and exhibit hepatoprotective and antineoplastic effects (Hatano *et al*. 2005). Some compounds such as anthraquinones and saponin are present in the *Aloe vera* gel and have direct antibacterial activity, while some other ingredients, such as acemannan, are thought to exert indirect bactericidal activity through stimulation of phagocytosis (Saritha *et al.*2010).

Anti-inflammatory action: The *Aloe vera* gel has been applied locally by ancient and contemporary cultures around the world for its anti-inflammatory action and the healing properties it offers to wound healing. *Aloe vera* contains at least three anti-inflammatory fatty acids, which are cholesterol, campersterol and beta-sitosterol. This explains why the use of *Aloe vera* is particularly effective in treating burns, cuts, allergic reactions, ulcers and many inflammatory conditions of the digestive system. *Aloe vera* contains at least 23 polypeptides that have an immunogenic stimulus role. Also, explains why *Aloe* can improve a wide range of diseases and disorders

of the immune system such as HIV and AIDS. The polypeptides, and the anti-cancer agents of emodin and Aloe lectins, explain the ability of *Aloe vera* to control cancer (Reuter *et al*. 2008; Myrogianni 2013).

Immunostimulatory action: A wide variety of natural molecules with immunostimulatory activity have been isolated from *Aloe vera* and other plants commonly used in traditional medicine in an empirical way (Grotenhermen 2004). *Aloe* has anticancer, antiproliferative, immunostimulatory, anti-inflammatory and antioxidant activity (Qureshi*et al.* 1993; Grotenhermen 2004). The antiproliferative action of *Aloe vera* and its immunomodulatory effects are derived from separate molecules. In particular, anti-tumor antiproliferative effects of *Aloe vera* are mainly exercised by aloe-emodine, whose action is oncostatic. It has been shown to be particularly evident against neuroendocrine cancer cell lines (Capasso *et al.* 1998). The immunostimulatory properties are predominantly dependent on acemannan and glucomannan (Myrogianni 2013).

Benefits of *Aloe vera:*

Detoxification: *Aloe vera* juice is ideal for detoxification because it is full of vitamins and minerals (Table 1). Consuming the juice can help our body cope with the demands of everyday life (Jyoti and Rajeshwari 2012; The Beauty Tonic 2012).

Table 1.Chemical composition and properties of *Aloe vera* (de Rodríguez *et al.*,2005).

Constituents	*Number and identification*	*Properties and activity*
Amino acids	Provides 20 of the 22 required amino acids and 7 of the 8 essential ones	Basic building blocks of proteins in the body and muscle tissues
Anthraquinones	Provides Aloe emodin, Aloetic acid, alovin, anthracine	Analgesic, antibacterial
Enzymes	Anthranol, barbaloin, chrysophanic acid, smodin, ethereal oil, ester of cinnamonic acid, isobarbaloin, resistannol	Antifungal and antiviral activity but toxic at high concentrations
Hormones	Auxins and gibberellins	Wound healing and anti-inflammatory
Minerals	Calcium, chromium, copper, iron, manganese, potassium, sodium and zinc	Essential for good health
Salicyclic acid	Aspirin like compounds	Analgesic
Saponins	Glycosides	Cleansing and antiseptic
Steroids	Cholesterol, campesterol, lupeol, sistosterol	Anti-inflammatory agents, lupeol has Antiseptic and analgesic properties
Sugars	Monosaccharides: Glucose and Fructose Polysaccharides: Glucomannans/polymannose	Anti-viral, immune modulating activity of acemannan
Vitamins	A, B, C, E, choline, B12, folic acid	Antioxidant (A, C, E), neutralises free radicals

b. Digestive disorders: *Aloe vera* has a substantial effect on digestive disorders such as heartburn, ulcers and irritable bowel syndrome. Specifically, it soothes the esophagus and reduces the pain in the gastroesophageal reflux. Thereby, it helps to improve bowel function (The Beauty Tonic 2012; Bahmani and Eftekhari 2013).

c. Oral hygiene: *Aloe vera* leaf juice can help you to visit the dentist less regularly, as it significantly improves the health of the gums (Bhat *et al.* 2011).

d. Diabetes: According to laboratory research, the daily consumption of only a half-pound of *Aloe vera* juice over a period of 14 weeks can reduce blood sugar by 45% (Shrivastava *et al*. 2011).

e. Weight Management: In addition to therapeutic properties, *Aloe vera* has been used in the past to help fight obesity and maintain a normal weight (Richardson *et al.* 2005).

f. Cuticle: Perhaps the best-known use of *Aloe vera* is its application and its positive effect on a number of skin problems. In addition to psoriasis, this plant is useful for hydrating and detoxifying the skin, removing scars and scars, fighting inflammation and general skin revitalization (Glaser 2004).

Possible Side Effects: In general, *Aloe vera* is a safe plant, provided it is used properly. You should always follow the instructions of your pharmacist or herbalist because prolonged or excessive use may have side effects: Women during pregnancy and lactation, but also those who have problems such as abdominal pain, ileal history or allergy to garlic, onion and other plants of this family, should avoid *Aloe vera* (Ahlawat and Khatkar 2011). *Aloe vera* can interact with hydrocortisone, diuretics, anticoagulants and diabetes medicines. Thus, it can, for example, improve the functioning of the pancreas, resulting in the need for adjustment of the insulin dose. Due to its cathartic effect, it can still drop

potassium levels in the blood and cause arrhythmias (Surjushe *et al.* 2008).

Adverse effects of *Aloe vera:* Recent studies and researches have been conducted and proved the potential of the *Aloe vera* whole-leaf extract carcinogenic activity. Some of them (Boudreau *et al.* 2013) are suggesting that the long-term exposure of rats to the *Aloe vera* whole-leaf extract induced an insult to the intestinal tract and caused a progression in lesion types from goblet cell hyperplasia to mucosal hyperplasia to adenoma and carcinoma in the large intestine (Boudreau *et al.* 2013). Moreover, Guo and Mei (2016) stated that due to its widespread human exposure and concerns that some components may cause cancer, in 1998 the National Cancer Institute nominated *Aloe vera* as a high-priority candidate for a carcinogenicity study under the National Toxicology Program (NTP).

Commercialization of *Aloe vera* in Greece: The main characteristic of the international market for medicinal and aromatic plants, in which Aloe is classified into (Greek Ministry of Rural Development and Food 2017), is the significant increase in market demand for the plant. A SWOT analysis follows, in order to investigate and analyze the strengths and weaknesses, at the level of production and distribution of the plant and its products, in the area of Greece (Table 2). The prospects and risks of the ventures must also be recorded and evaluated so that, combined with the strengths and weaknesses, to allow an overview regarding the commercialization of Aloe in Greece.

Table 2. SWOT analysis of *Aloe vera* in Greece.

Strengths	Weaknesses
● Adaptation in the Greek climatic and bioclimatic conditions. ● Relatively easy (non-demanding) cultivation and use of organic fertilization. ● Shows excellent durability. ● Strong interest of consumers in North America and Europe to use natural products for health care. ● The last years, there has been a keen interest in growing aloe plants at both amateur and professional level.	● The main problem for producers, other than the lack of information, is also the difficulty of distributing the *Aloe vera* leaves. ● There is only a small number of leaf-processing units. ● Risk of extinction of rare plants at the local flora. ● Problematic supply chain. ● Insufficient storage conditions that negatively impact on product quality. ● Export constraints and prohibitions. ● Inefficient quality check.
Opportunities	**Threats**
● Development of research activities, in the direction of utilization of aromatic and medicinal plants. ● Development of the cosmetics and pharmaceuticals manufacturing industry, which use as ingredients the *Aloe vera* plants. ● Development of the food industry in the direction of production of food products which contain aloe. ● In general, the cultivation of aloe can be regarded as economically viable, with a relatively small degree of farming currently.	● Advantageous price of drugs /other nutritional or health care natural products. ● Fluctuating quality of production. ● Seasonality in production that does not cover the fixed seasonal demand of the industry. ● Risk of natural disasters. ● Risk of reduced harvests. ● High cost of quality certification

Economic sustainability of *Aloe Vera* crop in Greece: Bassetti and Sala (2005) argue that Spain, Greece, and Israel constitute the most efficient areas on a global scale, for the production and supply of organically grown *Aloe vera*. The Greek farmland, in areas such as the islands of the Aegean Sea, Crete and Peloponnese, is suitable for the economic utilization of the plant, especially with the global increase in market demand for the plants' gel (Piña Zambrano *et al.* 2013), due to the tremendous applications that present a potential in the sectors of medicine, cosmetics, food and dietary supplements (Christaki and Florou-Paneri 2010; Maan *et al*. 2018).

Liontakis and Tzouramani (2016), through their research, performed exclusively in Greece, by personal interviews with 33 *Aloe vera* producers, attempt to assess the economic performance of Aloe in the Greek territory. The authors identified two sources of business risk that are incorporated in the farming of *Aloe vera*. The first has to do with the plant itself, as an agricultural product, and the variation in production, due to the environmental conditions and the agrarian risks that exist in every cultivation (fertilizers, disease, etc.). This variation leads to differentiation in the annual yield, especially with the complete lack of national agricultural insurance.

The second source of risk is relevant to the market channels and their development in the country. As they are still in an embryonic stage (Vagenas 2014), along with the sector of processing the gel, the market channels are not able to ensure stable price levels and consistent total volume levels, which can be distributed in the market. The market channels that exist in Greece are small processing units which operate locally, a few retail markets, in the sectors of food and medicine (pharmacies, supermarkets, etc.) and a limited number of direct sales to end-consumers, at high prices achieved for the producer.

The cultivation of *Aloe vera* in the Greek territory and its commercial utilization, is growing at steady rates (Hellenic Association of Aloe Organic Farmers 2018), despite the lack of effective and efficient market channels that will align the production with the market demand. The profile of the Greek producers who cultivate organic aloe is small family farms which seek sustainable new opportunities, apart from the traditional cultivations, possess farmland poorly irrigated and are unsusceptible to risk, whereas the more organized farms, are more hesitant to convert to the cultivation of Aloe, without the reassurance of achieving economies of scale (Liontakis and Tzouramani 2016).

Problems that arise from the commercialization of *Aloe vera:* The most important drawback in the market, regarding the commercialization of aloe is the adulteration of the final products. The most common alteration of the composition of the aloe-derived products is achieved through the addition of maltodextrin, as a substitute to glucose (Mulay *et al.* 2013). The presence of maltodextrin is more common in products derived from the processing of the inner leaf, as it is added to reinforce their polysaccharide content. In order to detect the alteration in qualitative as well as quantitative levels, the technique of Nuclear Magnetic Resonance Spectroscopy (HNMR), should be implemented. Another method of aloe adulteration is the addition of water, which dilutes the final product and reduces the effect of its active substances, as the products are usually gel concentrate (Herzberg and Gruenwald 2003). The majority of the cases regards the production of aloe-derived products, from species other than *Aloe vera* (Vagenas 2014).

The reason for this situation is the lack of an explicit and definite legislative framework in Greece, which will control the use of Aloe and set widely accepted specifications. Currently, in Greece there are no legal provisions regarding the maximum levels of aloin contained in aloe juices and beverages. The market seems to be in compliance to the International Aloe Science Council (IASC), which is a global quality and certification organization, based in USA that provides a mechanism and certain quality standards, which the *Aloe vera* raw materials and end products should contain (IASC 2018).

Conclusion: The current study focuses on the latest evidence base information regarding cultivation, utilization and, commercialization of *Aloe vera* crop in Greece and generally in the Mediterranean area. It is concluded that *Aloe vera* holds a vital role in herbal medicine and is considered to be a nutritional storehouse, with multiple benefits to the human health. During the last decade, *Aloe vera* has shown increased growth rates as it comes to cultivation even though when commercialization and market demand in the area of Greece are in embryonic stage. The demand for aloe-based products has expanded internationally especially in the sectors of medicine, food, cosmetics, cultivation and utilization. It is remarkable that there is a promising future of this plant in Greece as it could be decisive in the treatment of present and future challenges, and in the decision-making of the research and scientific community. In the end, as far as the prospects are concerned, *Aloe vera* is an alternative crop to dry heat conditions, but it requires a risk from farmers' side and a financial aid from the State, in order to overcome the problem of the large initial investment in equipment for various post-harvest operations. Consequently, more exploratory studies are still required to confirm and justify use of the *Aloe vera* in pharmacognosy section of Greece.

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