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Overview of *Dioscorea deltoidea* Wall. Ex Griseb: An endangered medicinal plant from Himalaya region

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Abstract

Dioscorea deltoidea is an endangered species belonging to family Dioscoreacea, It produce rhizomes or bulbils which is rich in sapogenin steroidal compounds. These compounds have immense medicinal, industrial and commercial importance. *D. deltoidea* is expectorant and sedative. It is involved in treatment of cardiovascular system, central nervous system, dysfunctional changes in the female reproductive system, disease of bones and joint metabolic disorders, skin diseases, oncology and immunodeficiency's and autoimmune diseases. Traditionally it is used as vermifuge, fish poison and kills lice. Diosgenin which is a steroidal aglycone is precursor to chemical synthesis of many hormones. *D. deltoidea* is commercially exploited for its bioactive chemical substances like diosgenin, corticosterone and sigmasterol. The aim of present study is to evaluate the medicinal properties, ethnobotanical uses, phytochemicals, pharmacological properties, threats and conservation strategies of *D. deltoidea*.

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Introduction

Extinction of species has become one of the most significant problems occurring throughout the world. This situation is even more worsening in the developing countries (Rahbek & Colwell, 2011; Tedesco *et al.* 2014). Over the last decade, conservation and preservation of the endangered species is the common interest of biologist and conservationists. Mostly, medicinal plants are over exploited and are becoming extinct. Since prehistoric times, medicinal plants have been used for the cure of various diseases. They are very commonly used by local people so many people are engaged in trade of medicinal plants throughout the world (Qureshi *et al.* 2009).

Thus, many plant species are exploited every day for their therapeutic potential. Different researchers have reported many uses of plants and evaluated their medicinal potential. It is reported that plant kingdom had contributed immensely to fulfill health needs of human being since the time when there were no synthetic medicines available and no concept of surgical management was existing (Sher *et al.,* 2000). Since today 25% of prescribed medicines contain the ingredients derived from plants (Qureshi *et al.*, 2009).

So these are under the influence of extinction. There is a strong need to conserve these plant species. Conservation of plants is not a simple process. It involves plant protection and controlling the access to plant resources. It also demands collection of baseline data on socio-economic and ecological parameters, so we can incorporate the data into comprehensive management strategy (Shinwari, 2010).

The country like Pakistan is rich in biodiversity hot spots; it represents diverse climate, topographical, latitudinal and phyto-geographical varying features. There are more than 6000 species with 428 endemic ones in Pakistan. There is a variation and controversy about the endangered flora of Pakistan, because of limited information on conservation of native species (Ali and Qaiser, 2010).

Among many plant species *Dioscorea deltoidea* is among the endangered species of Pakistan. This species is reported as highly medicinal due to its compounds. In Pakistan, there is very limited information is available about this species in documented form.

The genus *Dioscorea* belongs to the family Dioscoreaceae in the order Liliales and class spermatopsida. It is a monocotyledonous genus with almost 300-500 species (Caddick *et al.*, 2002). Among which *D. deltoidea* is a climbing herb with rhizomatous rootstock (Dangawal and Chauhan, 2015). It is mainly occurs in the tropics and subtropics region of the world. The genus *Dioscorea* was named after the ancient Greek physician and botanist, Dioscorioids (Dangawal and Chauhan, 2015). Most of the *Dioscorea* species are herbaceous climbers with rhizome or tubers. In most species the rhizome which annually produces shoots is enlarged to develop as storage organ (Ali, 2012).

Presence of different steroidal compound is increasing the demand of species for isolation purpose. A number of diseases are cured by different phytochemical compounds of *Dioscorea*. For this purpose it is exploited intensively threatening its survival. The species need to be conserved and different strategies are required to be adopted.

The aim of present study is to explore the uses and their ethnopharmacology to elaborate its worldwide demand. It can help us to analyze the conservation status of *Dioscorea deltoidea* by combining its distribution, medicinal uses, with spatial data identifying the threats and their relative exposure.

Distribution

It is distributed throughout the tropical and subtropical regions in the world, mainly in West Africa, parts of Central America and the Caribbean, Pacific islands and South East Asia (Anand, 2011). In Asia, the plant is found mainly in Cambodia, Bhutan, Afghanistan, China, Pakistan, India (Western Himalaya), Nepal, Vietnam and Thailand.

Its habitat is found ranging from 450 to 3100 m altitude. In Himalayas it is found at altitude of 2-9000 feet (Gopichand *et al.,* 2013). It is found in forest clearings, shrubberies, slopes and rocky substrates.

Ali (2012) reported that in Pakistan this species has been reported in Chitral, Dir, Swat, Bahrein, Kalam, Shonala, Hazara, Kagan Valley, Galis, Kurram, Murree, Kashmir, Ladak and in few areas of Punjab.

Fig. 1. Map representing distribution pattern of *Dioscorea edeltoidea*.

Classification

According to Govaerts *et al.* (2007) this species can be classified as:

1. Kingdom= Plantae – Plants
2. Subkingdom= Tracheobionta – Vascular plants
3. Superdivision= Spermatophyta – Seed plants
4. Family=Dioscoreaceae
5. Division= Magnoliophyta – Flowering plants
6. Class= Liliopsida – Monocotyledons
7. Genus= *Dioscorea*
8. Species=*Dioscorea deltoidea*

Vernacular Name

It has various names in different languages, some well-known names are;

1. English name: Wild yam, Elephant's foot (Ali, 2012)
2. Hindi: Gun, Kin, Singly-mingly (Saikia*et al.* 2011)
3. Sanskrit: Varahikand (Ali, 2012)
4. Urdu: Qanis(Rokaya and Sharma, 2016)
5. Kashmir: KildriKreench
6. Punjabi: Kitra, Kniss (Ali, 2012) (Rokaya and Sharma, 2016)
7. China: Sanjiaoyeshuyu
8. Nepal: Bhyakur, Tarul, Ghunar (Rokaya and Sharma, 2016).

Botanical description

Dioscorea deltoidea is a perennial climber. Mostly it is found growing upto 3m (10 ft) in height. It is a hairless vine that is twinning clockwise. Rhizomes are ligneous (resembling wood), irregular, horizontal and alternately arranged. They may resemble ginger like shape. Stem is also twining, drying and have a purplish brown to brown groove. Leaves are alternate, simple, 5-11.5cm long and 4-10.5cm broad (Saikia *et al.*, 2011). Morphology of leaves show that they are triangular ovate, long pointed, often heart-shaped, 7-9 nerved, hairless on upper side and velvety on the nerves beneath. Leaf stalks are slender, 5- 10cm long. Flowers usually are small, distant in clusters with 6 stamens and inferior anthers. Male flower spikes are solitary in leaves axils. They may be simple or sometimes branched slender, 7.5-25cm long. Female flowers are stalked, solitary and slender up to 15cm long. Capsule usually may be reflexed brown at maturity and purplish brown spots are observed.

Capsule is oblong-ovoid or globose with rounded base and emarginated apex. Seeds are inserted near middle of capsule in ovate manner (Saikia *et al.*, 2011; Ali, 2012).

Flowering occurs usually in May to June and fruiting occurs from June to September (Rokaya and Sharma, 2016).

Fig. 2. *Dioscoreae deltoidea* in its Natural habitat.

Cultivation

Dioscorea deltoidea grows best in temperate region with well drained loamy soil rich in humus and organic contents. It needs shade and moisture to grow well. It is cultivated in homes usually. It is also cultivated by the efforts of various industries. Usually 50-60gm tuber pieces carrying 1-2 buds are used commercially for its mass propagation. Plantation is usually followed in rainy season (Hussain, 1992; Mulliken and Crofton, 2008).

In Pakistan, it sprouts after the melting of snow in April-May and flowers in June-July, while fruits ripen in August-September (Rokaya and Sharma, 2016). Although no commercial cultivation exists in but agro-technology has been developed by some research institutes.

Phytochemistry

Different phytochemicals are found in *Dioscoreae deltoidea* which are reported by different workers. These include diosgenin, 25-D-spirostan-3,5 diene, smilagenone, stigmasterol, B-sitosterol, dioscorin, dioscin and campastrol. Root contains phytosterols, alkaloids, tannin and rich source of starch.

Diosgeninis a chemical substance found in *Dioscorea* and are used commercially in pharmaceutical industry (Dangawal and Chauhan, 2015).

These phytochemicals are well known steroidal glycosides. These steroidal glycosides possess hypo-cholesterolemic, hemolytic, antitumor, antimicrobial and fungicidal activities (Shah, 2010). Subash *et al.* (2012) reported that experimentation has proven the presence of carbohydrates and glycocides, alkanoides, flavonoids, tannin, saponin, unsaturated triterpinoides, resins and sterol from the extract of *D. deltoidea*. Other substance found are ascorbic acid, aluminium, ash, beta-carotene, riboflavin, calcium, chromium, cobalt, iron, magnesium, manganese, niacin, phosphorus, potassium, protein, selenium, sodium, silicon, thiamine, tin, zinc. These compounds and substances make this plant an industrial plant (Dangawal and Chauhan, 2015).

Ethnobotanical Importance

For ethnobotanical evaluation researchers found similarities in the use of this species in different regions. It is used to get relief from the intestinal worms.

It acts as a vermifuge (worm repellent) for children specially. Its roots are found being active against uterine sedative.

It is diuretic expectorant in major regions of Himalaya and KPK ((Hamayun, 2007; Ali, 2012; Dangawal and Chauhan, 2015).

Fig. 3. (A) Whole plant of *Dioscorea deltoidea*. (B) Unequal round winged shaped seeds of *Dioscorea deltoidea* (C) Matured Leaf (pointed Heart shaped 5-11.5cm long, 4-10.5cm broad) of *Dioscorea deltoidea*.
(D) Underground Rhizomes of *Dioscorea deltoidea*.

It is also used as bio-poison for fishes reported by Razaq *et al.* (2010) in Changa Manga and Hamayun (2007) in Swat. Its tubers are employed to treat bilious colic and to kill lice. Its roots contain good amount of diosgenin used as starting material for hormone preparation. It is also used in soap making due to its saponin content (Muslim and Sikander, 2010). Studies indicate that it was used to wash clothes as detergent because of saponins present in this species. Traditionally *D. deltoidea* is found to be anti-rheumatic and treat ophthalmic conditions (Jain, 1975). Kumari *et al.* (2012) reported that the powder from rhizome of plant is taken orally to cure dysentery, abdominal pain and piles.

Abbasi *et al.* (2013) reported in lesser Himalayan region and Mediterranean regions that flowers and rhizome of some vegetables is fried in ghee along with *D. deltoidea*. Its rhizome (2-3gm) is also given orally to get relief from snake bite. It is found to be used to wash clothes at the time when soap was not available (Chauhdry *et al.*, 2008; Hussain *et al.*, 2012). The preparations of *D. deltoidea* from tubers or rhizomes are used in the treatment and prevention of the diseases of the central nervous system (CNS), cardiovascular system, dysfunctional changes in the female reproductive system, orthopedic disorders, metabolic disorders, oncology, dermatitis and autoimmune diseases (Dangawal and Chauhan, 2015). Another traditional use evaluated shows that the corm of the *D. deltoidea* is dug out from the soil. The rough and hairy skin of the corm is peeled off and cut into very thin slices. Then these slices are beaded into a necklace and dried under the sun. These dried slices are converted into powered form and stored in the jars (Khan, 2012).

Commercial value

As *Dioscoreae deltoidea* is well known because of its phytochemical compounds. It has great commercial potential. It is used in herbal allopathic and other medicinal systems. As a source of steroidal sapogenins, it has gained much repute across the world. Steroidal sapogenin diosgenin is precursor to many steroidal hormones (such as progesterone, corticosteroids and anabolic steroid). This diosgenin is also useful in the treatment of rheumatic arthritis. It is used in preparation of sex hormones (Ali, 2012). Diosgenin and other phytochemical compound are the reason for its commercial exploitation and immense pharmaceutical and industrial use.

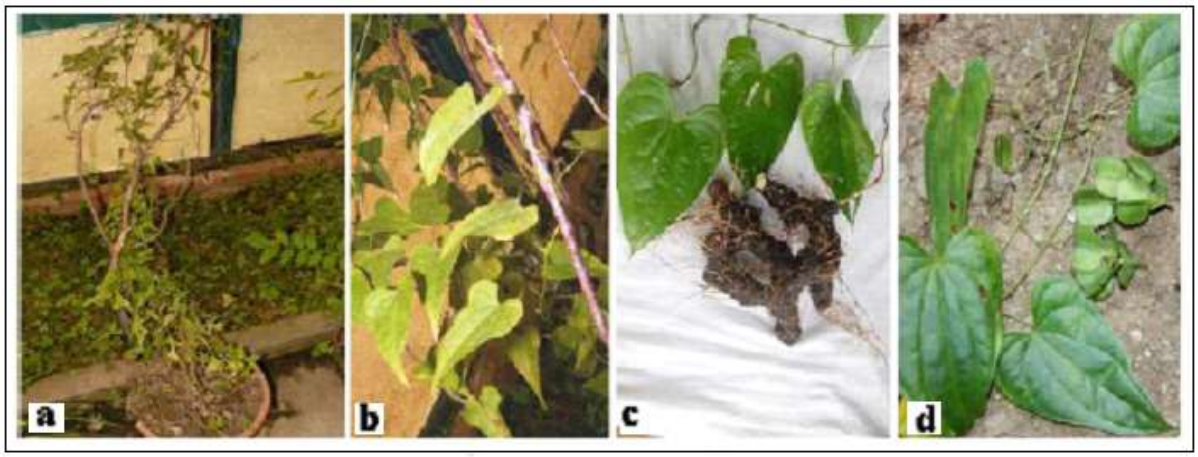

Fig. 4. a) *Dioscoreae deltoidea* plant (b) *D. deltoidea* plant growing with woody support (c) Mature leaves with root stock (d) Mature leaves with fruits.

Harvesting and processing

The optimum harvesting time is considered when plants reach their maximum size after three years or when becomes dormant (Saika *et al.* 2011). Before the emergence of buds (dormant stage) during November-March, it is believed that diosgenin and yaogenin contents are highest. So it would be the best time to harvest (Gopichand *et al.* 2013). Collection of rhizome mainly takes place in cool, moist and shady place. It involves digging to collect rhizomes (Dangawal and Chauhan, 2015). Rhizome collection is usually carried out by the indigenous women and children, as it involves digging too sometimes man also help their woman in its digging. After harvesting tubers are washed in running water. Then it is kept in an open space but under shade for few days to dry out. The numbers of days depend upon temperature and humidity. Afterwards, dried shoots and tubers are stored in moisture free bags at room temperature (Shinwari, 2010).

Biodiversity threats

One of the important threats (though indirect) is the collection of medicinal herbs from their core habitat. Their high demand is the reason for their over collection. Uprooting results in decreased soil binding. As a result, soil erosion and land sliding occur followed by snow avalanches. The threat is being reported in many other cases too (Smith & Larsen, 2003; Shinwari & Qaisar, 2011).

The arranged field visits in search of some plants containing active ingredients by herbalists and chemists is also a threat. These organized field visits lead to over collection. *D. deltoidea* is well known for its active ingredients and metabolites. It has a potential threat for commercial collection. Its increasing marketing demand has posed a tremendous threat to the species (Kala *et al.* 2004; Kala, 2005; Larsen & Olsen, 2007). This species is reported to be endangered in India and Nepal due to over exploitation and industrial use (Dangawal and Chauhan, 2015; Das *et al.* 2013; Rokaya and Sharma, 2016). Over collection is also done for research and educational studies. It involves collection for studying therapeutic potential, investigating different compounds and their potential action (Shinwari, 2010). Over collection usually lead to habitat loss. It threats all the biomesrepresenting high rate of extinction of species. Habitat fragmentation isolates the vegetation in small pockets making it more vulnerable to genetic loss. Increasing human population demands more food, medicine, shelter, land and other resources. This has led to destruction of natural habitat and deforestation (Saxena *et al.,* 2003; Shinwari *et al.*, 2012). In upper regions of Pakistan, over collection, uprooting, deforestation, storms are leading to soil erosion. Not only soil, wind and water erosion are also responsible for reducing vegetation cover.

Sedimentation of wetlands and habitat degradation are thus occurring (Shinwari, 2010). Currently, dynamic climatic changes like rainfall fluctuation, rising global temperature, melting glaciers, ozone depletion, water shortage, population pressure, and pollution are strongly influencing biodiversity in Himalayan region. As a result life of flora and fauna both are threatened. Many studies are predicting that 2-3°C rise in temperature over next country can threaten as many as half of species leading to extinction. This shows that *D. deltoidea* is also being threatened due to climatic change, deforestation, over collection and erosion (Ahmad *et al.* 2015). Permanent monitoring programs should be developed and conservation strategies should be planned to maintain threatened species (Sidra *et al.* 2016).

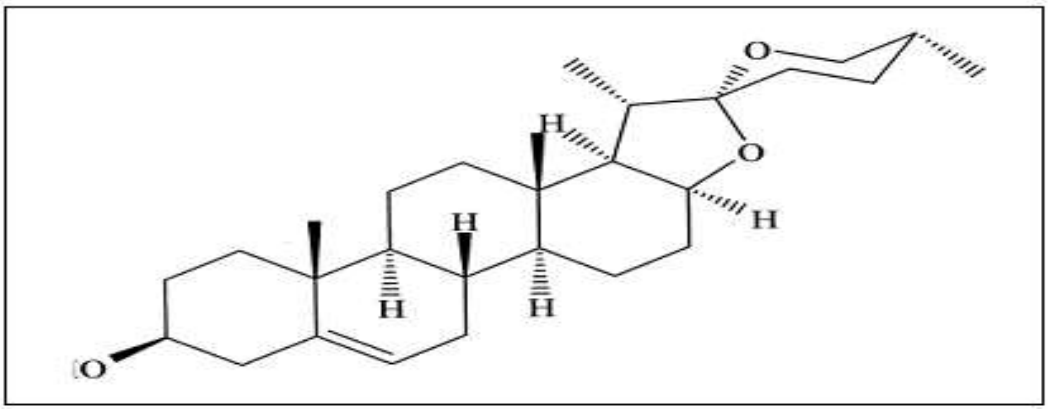

Fig. 5. Diosgenin- Phytochemical of *D. deltoidea*.

National and international trade

Dioscoreae deltoidea has more trade value than being used locally. It is continuously available in national and international markets. In Pakistan, exporting plants is rising day by day, making them endangered (Shinwari, 2010). According to an estimate traded plants rose to a greater extent from Rs. 36 million in 1990 to Rs. 218 million in 2002 (Shinwari, 2010). It is found that 19, 20,000 kg of *D. deltoidea* is exported to India (Hamayun *et al.,* 2003). This shows that most of the medicinal plants are transported to India from Pakistan from Swat. Its trade route is given in following figure.

Trade legislation

CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. *D. deltoidea* is included in CITES on 1st July 1975 in Appendix II under Annotation No.1 (Schippmann, 2001). According to this the plant species obtained from wild is prohibited from trade. Only cultivated or artificially propagated plant species can be exported. For its export legal procurement certificate or certificate of cultivation is required from designated authorities. However formulation of seedling and tissue cultures techniques are allowed (Ali, 2012).

Conservation methods

Conservation of a plant can be achieved by using different techniques. Usually two types of conservation methods are well known;

1. *Ex-situ* conservation.
2. *In-situ* conservation

In situ conservation

Involves area specific action plan and natural sites are considered to be the most important aspects of in situ conservation activities. For this purpose national parks and biosphere reserves are targeted. In Pakistan, *D. deltoidea*is protected in Ayubia National Park (Saima *et al*., 2009), Margalla Hills National Park (Jabeen *et al.,* 2009), Toli Pir National Park (Faiz *et al.* 2014) and Palas Valley (Saqib and Sultan, 2005).

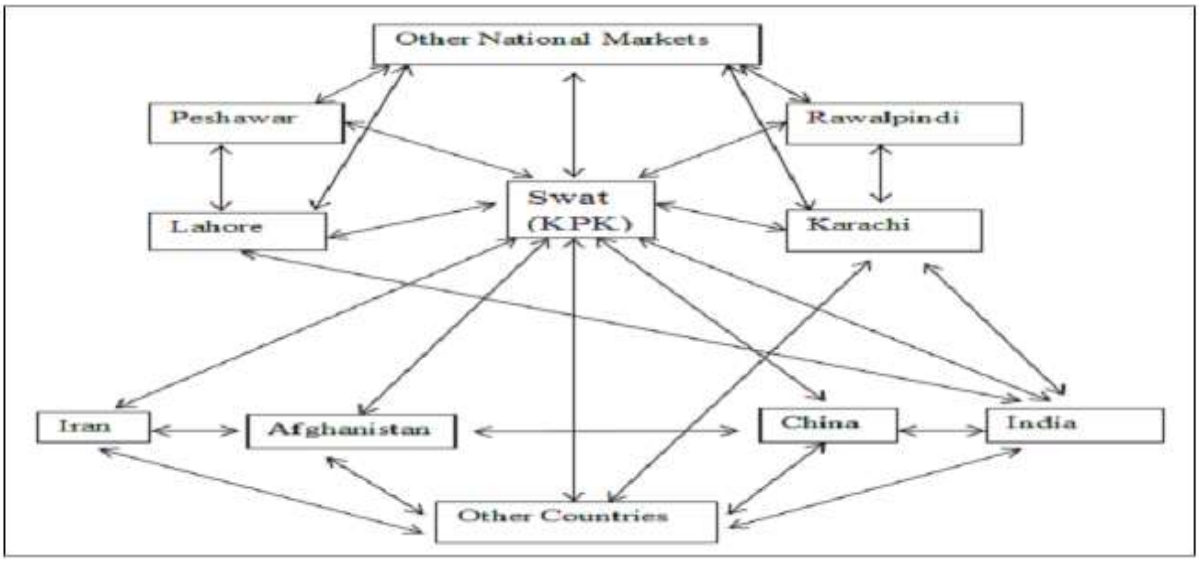

Fig. 6. National and international trade route of *D. deltoidea* given by Hamayun *et al.* and Shinwari.

Ex situ Conservation

Involves the process of protecting an endangered species and developing it outside its natural habitat. For this purpose, plantation of medicinal plants on private land through seedlings and vegetative parts is carried. Usually local people of Northern Pakistan are interested to cultivate the species (Sher and Hussain, 2010). A project named "Innovation of Poverty Reduction Project" with the cooperation of "Swiss Developmental Corporation Project" is also established. The aim of this project is to improve the community livelihood by training them to harvest and cultivate medicinal plants. This may help to reduce poverty and improve the livelihood and income level of the remote areas of Khyber Pukhtun Khaw through better management of natural resources (Hussain and Rehman, 2015). Micropropagation of *D. deltoidea* has been achieved through rapid proliferation of shoot-tips axillary buds in culture. Several factors are reported to influence the growth of *in vitro* propagated plants. Different explants like stem, seed, inflorescence or tuber are used by different researchers to propagate the plant. It has proven successful to a greater extent (Das *et al.* 2013). Plant tissue culture technique has been successfully used to produce high yielding plantlets that are not only used in rapid multiplication but also conserved in *in vitro* gene banks.

Additionally to this indirect method like callogenesis and somatic embryogenesis can be applied for production of plantlets helping in establishment of large scale plant nurseries (Hussain *et al.*, 2016; Iqbal *et al.*, 2016) Ali *et al.*, (2013) established a protocol for synthetic seed production by using artificial coating material (sodium alginate) and complexing agent (calcium chloride). This synthetic seed technology can also be very helpful for medicinal plants such as *Dioscoreae* species. Transportation results in low survival rate, during transplantations but plant can be preserved to some extent. Micro-tubers produced from *in vitro* plantlets have been proposed as an additional means of germplasm conservation and propagation. The use of artificial (synthetic seeds in storage and germplasm conservation has also been reported. These seeds are encapsulated somatic embryo that can grow into a plantlet. For long term conservation use of artificial seeds for cryopreservation (via encapsulation, verification and encapsulation dehydration) is reported. Cryopreservation is a process where micropropagules are usually preserved by cooling at low to subzero temperature such as 77K or -196^{o}C (Balogun, 2009).

Institutes and Working Projects on Conservation Strategies of Dioscoreae deltoidea

Different institutes are involved in efforts to conserve *D. deltoidea* with other medicinal plants, these are; Pakistan forest institute (PFI),

IUCN (International Union for Conservation), WWF (World Wide Fund for Nature), European Union, and a German aid agency (GTZ), and Educational institutes are also involved in conservation under the support of Higher education commission (HEC) of Pakistan (Shinwari, 2010). In Pakistan, although very little attention is given to conservation of plants.There are some projects carried out by governmental and non-governmental institute to protect and conserve the medicinal plants of Northern Areas and Himalayan regions. These projects are;Ethno-botany Project for the Hindukush and Himalayas, The European Union (EU) project, Environmental Rehabilitation in NWFP and Punjab, Joint Forest Management project in Mansehra (NWFP) (Shinwari, 2010) and Palas Conservation and Development Project (PCDP), Kohistan, NWFP (Saqib and Sultan, 2005). Permanent monitoring programs should be developed and conservation strategies should be planned to maintain threatened species (Hussain *et al.*, 2016; Sidra *et al.*, 2016).

Conclusion

Pakistan is rich with species diversity because of its unique topographical features but conservation of these resources is neglected as compared to other Asian countries. *Dioscoreae deltoidea* is also an important medicinal herb. It is exported more than being used in local market. Major export material goes to India. It is neglected in Pakistan. In Pakistan very limited work is being done on this species. In India and Nepal lot of work is being done including its ethnopharmacology, biochemistry, pharmacognosy, conservation strategies and legislative rules. But in Pakistan it is evaluated only for its ethnobotanical studies in some areas. There is an increasing demand to collect baseline data on its socio-economic, ecological and ethnobotanical parameters. Although some projects are being carried out but efforts are required to conserve it, before it reaches to extinction.

There is a need to initiate awareness programmers among local people to ensure the protection of this species. Proper training should be given to collectors and local people and educating them is very important.

There should be collaboration between collectors, buyers, shopkeepers and industries to ensure a proper management of the resource material. Cultivation in private land and different areas should be encouraged. Marketing and trade should be checked strictly. Conservation strategies are which are successful in other countries, should also carried out in Pakistan.

There is a need of trained and skillful personals to handle and take care of endangered species. Methods and strategies should be developed for sustainable use. Proper management and protection is important. Rules and Legal framework should be developed to conserve the species. Conservation is a cost effective methoddue to that collaboration with governmental and non-governmental agencies should be carried, and grants and aids should be sustainably used.

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