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Abstract

Species of *Indigofera* are important source of forage particularly in hot arid region and temperate areas. *I. oblongifolia* is one of the important underutilized leguminous browse shrub for small ruminants in hot arid region of India and traditionally utilize for its medicinal value. Its irregular patchy distribution was observed in depression of rocky areas, bunds of farmer fields and along the depression on the road sides in Jaisalmer and Pali district during collection. Soil samples collected from Pali district have high level of pH and electrical conductivity as compared to Jaisalmer which indicates its suitability to saline areas. It exhibited good plant growth in Jodhpur with respect to plant height (171.5 cm), number of branches (47.9) and canopy diameter (100-210 and 115-180 cm in north-south and east-west direction, respectively) after twelve months of planting in fields under protected condition. Phytochemical analysis revealed the richness of its leaves on total phenols, flavonoids and antioxidant capacity and its suitability as a browse species to ruminants in rangelands. The present study provides scientific information on distribution, browsing value, plant growth and traits variation, phytochemical, and its potential for forage and medicinal value for its sustainable utilization in rangelands of the Indian hot arid region.

Keywords Browse · *Indigofera oblongifolia* · Medicinal value · Phytochemicals · Plant growth · Thar Desert · Underutilized

Introduction

Indigofera is an important genus of hot arid region of India but had received very little attention (Singh and Beniwal 2005) for sustainable utilization in rangelands. It is well represented by 10 species occurring in different habitats of western Rajasthan (Bhandari 1990). A new species, *I. jaisalmerica* has also been reported from Jaisalmer district of Indian desert by Purohit and Kulloli (2021). Species of *Indigofera* could withstand adverse environmental conditions such as extremes of temperature and drought in Thar Desert besides overgrazing. They can also grow on a wide range of soils and rainfall as well as of temperature. Most of the *Indigofera* species are in wild state and grazed by animals particularly sheep and goats and also used as cut and carry fodder. Due to heavy grazing pressure, many of the species and their ecotypes are on the verge of extinction particularly in Thar Desert (western Rajasthan). The seeds of some of the species like *I. cordifolia* Heyne ex Roth are also the source of food during the times of scarcity and famine. The genus *Indigofera* received attention earlier in regard to chemotaxonomy (Bhalla and Dakwale 1978; Mishra et al. 1981) and also for anatomical studies (Kumar 1983). Anuradha et al. (1987a) studied the nine species

of *Indigofera* for distribution of different secondary metabolites, phenolic compounds and amino acids. Among the different species, *I. oblongifolia* is one of the important underutilized multi-use leguminous shrub traditionally used for forage, medicine and herbal tooth-brush. It is an erect arid shrub occupied open dry areas with stable sandy soils in the region. Relatively little scientific work has been done for exploitation of its potential for multipurpose utilization and development in hot arid region of India. Therefore, present paper highlighted the botanical description, economic importance, distribution pattern, browsing value, plant growth and trait variation, phytochemical and pharmacological value of *I. oblongifolia* and its exploitation potential for hot arid rangelands.

Botanical description

I. oblongifolia Forssk. (Syn. *I. paucifolia* Delile) belongs to family Fabaceae. It is a tall woody, erect much branched, ashy-grey shrub that become more or less woody, especially near the base. Leaves are simple or imparipinnate; leaflets (1-) 3-5, alternate, elliptic-oblong, more or less hairy above and silvery hairy beneath. Flowers are small, in many flowered, axillary racemes and red. Pods are densely silvery when young, dirty reddish at length, slightly up-curved, tortulose and 6-8-seeded (Fig. 1e). Seeds are obliquely oblong-globose, yellow and smooth (Fig. 1f). Flowering and fruiting occur from September to March, however, it may be throughout the year if conditions are favorable (Bhandari 1990; BSI 2022).

Vernacular names

Western Rajasthan - Goilia, Jhil; Sanskrit - Raktpala; Hindi - Goilia; Gujarat - Jhil, Jhiladi; Tamil - Kuttukara, Sammati, Kauttukkar chammathi; Kannada - Janglineeli; Telgu - Kondavempali; Arabic - Afar, Hasar, Hissar, Widmeh; and Madagasksar - Ingitrala.

Distribution and habitat

It is widely distributed in Jordan, Yemen, Baherien, Eritrea, Somalia, Egypt, Sudan, Senegal, Angola, Nigeria, Arabia, Baluchistan, Pakistan, Java, Sri Lanka, India (Bhandari 1990; BSI 2022) and also in Australia and North & South America (Lubbad et al. 2015). In India, it is distributed from Upper Gangetic Plains to Peninsular India, Rajasthan and also in Gujarat. In Rajasthan, it is reported from different locations from Banswara, Barmer, Jaipur, Jhalawar and Sawai madhopur districts (Shetty and Singh 1987). In western Rajasthan, it mainly occurs in Barmer, Bikaner, Jaisalmer, Jodhpur and Pali districts.

It is found especially near the coast, growing on edges of brackish places, stream sides, grassland, bush land, stony ground; sandy thickets, areas disturbed by human activity, at elevations up to 1200m. In Rajasthan, it occurs in gravelly calcareous soil or on older alluvial plains. This species generally grow in open sun light, preferring a well-drained but moist soil. Many of the species will also succeed in drier conditions and in poor soils. This is found on a variety of soils, ranging from black clays to sandy soils.

Economic Importance

Fodder

It is leguminous, non-thorny arid shrub reported to good browse species in western Rajasthan. Its leaves are grazed by goats, sheep and camels and have ability to survive under high browsing pressure in extreme arid condition (Fig. 2).

Medicine

Several species of *Indigofera* are traditionally used to cure many diseases and ailments. *I. oblongifolia* is known as Raktpala in Ayurveda is an important medicinal species in arid and semi-arid regions. In Ayurvedic formulation, its roots are used as cooling agent, improve appetite, and rheumatism. All parts of plant are useful in enlargement of spleen and liver (Kirtikar and Basu 1975). It is considered as an antidote to all kinds of poison and used as an anti-inflammatory for insect stings, snakebites, and swellings. Roots are used as purgative and stem decoction as a gargle in mercurial salivation (Caius 1989). It is also used as a cure for stomach-ache (Bhandari 1990). Saharias and Damors take orally the fresh juice of plant with sugar or "Gur" to cure liver diseases, diarrhea and rheumatism (Singh and Pandey 1998). Aggarwal et al. (2011) also reported that *I. oblongifolia* is used traditionally in folk medicines to treat infection of the urinary tract and skin, dissolved urinary stones and to relieve coughs. Leaf decoction is used to remove dandruff, leaf juice given in spruce, crushed leaves applied on wounds and leaves to treat abdominal gas in veterinary (Quattrocchi 2012). In Barda hills, Gujarat, Joshi and Nishteswar (2014) reported that whole plant ash of *I. oblongofolia* with oil used in animal healthcare for treating traumatic wounds and non-healing ulcers, also used in urticaria of camels. The whole plant is also given with Avartani (*Helicteris isora*) leaves and salt in acute indigestion conditions of animals. Its tender branches are commonly used as tooth brush in rural areas and also by Kathodi tribals in Rajasthan (Gupta et al. 1966; Bhandari 1990; Singh and Pandey, 1998).

Dye

Species of *Indigofera* are well known for preparation of dye in India since ancient times. Some of the species of *Indigifera* like *I. tinctoria* L., *I. caerulea* Roxb, *I. dosua* Don are used as blue dye, however, *I. tinctoria* was once the main source of blue dye production in India. *I. oblongifolia* is not used as dye plant in India, however, utilized as dye plant in Mali and Zimbabwe (Mansfeld 2001).

Green Manure

The species of *Indigofera* are traditionally used for green manure in India especially in southern part of India. It is reported to be extensively employed as green manure (Singh et al. 1996).

Materials and Methods

Survey and germplasm collection

Field surveys were undertaken in four districts *viz.,* Barmer, Jaisalmer, Jodhpur and Pali of western Rajasthan of India. The germplasm in the form of fruits (pods) were collected during fruiting stage in the month of October to December. The passport information of collected sites (Table 1), associated vegetation and conservation status of species were also noted during field survey. The ethno-botanical uses and distribution pattern was also noted by

interviews with local people. The secondary information was also collected from available literature to supplement the primary information.

Basic soil analysis

Soil samples were taken from collection sites and analysed for pH, electrical conductivity (EC), soil organic carbon (SOC), available phosphorus (P) and available potassium (K) at ICAR-Central Arid Zone Research Institute, Jodhpur. The collected soil samples were air-dried and sieved with a 2 mm screen and subjected to physical and chemical analyses using following standard analytical procedures. The pH and EC (dS m^{-1}) were determined in supernatant solution of 1:2 soil: water suspensions (w/v) using pH meter and conductivity meter, respectively (Jackson 1973). SOC (%) was determined by rapid titration method (Walkley and Black 1934). Available phosphorus (kg ha^{-1}) and available potassium (kg ha^{-1}) were estimated using colorimetric (Olsen et al. 1954) and flame photometer (Pratt 1982) methods, respectively.

Field establishment and evaluation for agro-morphological traits

The seeds were extracted from collected pods and dried at room temperature. Five seeds were sown in polythene bags prepared with soil mixture of sand, silt and FYM (1:1:1) in nursery. Field repository of *I. oblongifolia* was established in Botanical Garden of ICAR-CAZRI, Jodhpur. Plant growth data *viz.* plant height (cm), canopy diameter (cm) in north-south and east-west direction, and number of branches per plant was recorded for one year of establishment in the interval of 3^{rd}, 6^{th} and 12^{th} month. Ten individual plants were subjected for morphological characterization using 11 important traits after one year of establishment as follows: Number of branches $plant^{-1}$, number of raceme $branch^{-1}$, raceme length (cm), number of pods $raceme^{-1}$, number of seeds pod^{-1}, terminal leaflet length (cm), terminal leaflet width (cm), lateral leaflet length (cm), lateral leaflet width (cm), pod length (mm) and pod width (mm). The data were statistically analysed and presented in form of minimum and maximum values, mean ± SE, standard deviation and coefficient of variance (CV).

Phytochemical estimation

The fresh leaves of *I. oblongifolia* were collected from field repository established at ICAR-CAZRI, Jodhpur for biochemical analysis. Total antioxidant activity and total flavonoid content were determined by the methods described by Benzie and Strain (1996) and Marghitas et al. (2007), respectively. Total phenolic content was estimated using Folin Ciocalteu assay (Singleton et al. 1999). Total saponin content was estimated by vanillin–sulfuric acid method described by Hiai et al. (1976) and total chlorophyll content was determined by DMSO (Dimethyl sulfoxide) reagent (Blanke 1992).

Results and discussion

Survey and distribution pattern

During the field survey in four districts of western Rajasthan *i.e.* Jaisalmer, Barmer, Pali and Jodhpur, its distribution was found in different natural habitats of only Jaisalmer and Pali districts. Whereas, literature and herbarium specimens indicated its occurrence in Bikaner, Ganganagar, Jalore, Jhunjhunu, Sikar and Sirohi districts

also. The passport data of collected *I. obongifolia* fruit samples were presented in Table 1. Its occurrence was observed at the range of 25.72–27.04 °N latitude, 70.87–73.47 °E longitude and 153.3–276.1 m altitude. During the germplasm collection from Jaisalmer and Pali districts in Rajasthan, it showed an irregular patchy distribution in depression of rocky areas and sometimes in the bunds of farmer fields, and also along the depression on the road sides. However, it's very good coverage along the road sides was noticed in Devikot site of Jaisalmer district (Fig. 2d). Under high browsing pressure, it becomes woodier, especially near the base and stem becomes dense, and bushy (Fig. 2b &c).

Associated species

The associated species observed in Jaisalmer district during field survey and collections were woody perennial in nature like *Acacia senegal* (L.) Willd.*, Salvadora oleoides* Decne.*, Euphorbia caducifolia* Haines*, Grewia tenax* (Forsk.) Fiori*, Capparis decidua* (Forsk.) Edgew.*, Calotropis procera* (Ait.) R.Br.*, Ziziphus nummularia* (Burm.f.) Wt. etc., however, in Pali district mainly two woody species were noticed as *Capparis decidua* and *Acacia nilotica* (L.) Del.

Edaphic characteristics

The soil samples collected from sites of *I. oblongifolia* from Jaisalmer and Pali districts revealed significant variation for pH, EC, soil organic carbon (SOC), available P and available K (Table 2). *I. oblongifolia* shows good growth in dry and poor soil conditions in arid region. The soils were dominantly alkaline in reaction, with pH ranging from 7.57-9.02 with a mean value of 8.27. The electrical conductivity (EC) varies from 0.09 to 16.30 dSm^{-1}. Wide variations in EC values could be due to use of poor quality water and inherent properties of soils of the Thar desert (Dhir 1977; Kumar et al. 2020). Results of the soil analysis revealed that SOC was low throughout the study area region, while available P and K was low to medium and medium to high, respectively. The values of SOC ranged from 0.14 to 0.76% with a mean of 0.34%. Results of SOC obtained under present study falls under the earlier report on the organic carbon status of western Rajasthan districts such as Jaisalmer, Barmer, Bikaner, Churu and Nagaur as extremely low (<0.50 %) (Kumar et al. 2020). The available phosphorus in the soils showed wide variability (1.12-23.52 kg ha^{-1}) with mean value of 12.04 kg ha^{-1}. As the mean values across the region suggests, in general the quantity is low to medium. The available potassium (K) ranged from 67.50 to 382.50 kg ha^{-1} with mean values of 226.81 kg ha^{-1} with an overall medium fertility rating. Comparatively, samples collected from Pali district showed high level of SOC and available K as compared to Jaisalmer district. It also showed high pH (9.02) and EC (16.30 dSm^{-1}) which indicates its suitability to saline areas. A study by Khan and Ahmad (1998) from Pakistan on effects of saline water irrigation on germination, growth and mineral distribution of *I. oblongifolia* revealed that sodium accumulating capability of it as foliar succulence in leaves and fruit wall compare to selective transport of Mg^{++} to leaves and accumulation of Ca^{++} in roots.

Grazing/ browsing value

Indian Thar Desert has a huge repository of naturally growing wild *Indigofera* species ranging from prostrate annual herb, erect perennial herb and shrub forms, which occur on a variety of landforms. Most of the *Indigofera* species

are used as fodder in arid region and are rich source of nutrients as they grow on wide range of habitats under low rainfall conditions. Tropical pasture legumes presently under cultivation are mostly exotic species like *Stylosanthes guianensis, S. hamata, S. humilis, S. scabra, S. viscosa, Macroptilium atropurpureum, M. lathyroides* etc. They are particularly suitable to semi-arid condition and could not perform well in harsh arid condition (Singh and Beniwal 2005). *I. oblongifolia* is one of the adapted hot arid legume browse species, very much preferred by sheep and goats. During the germplasm collection of the *I. oblongifolia*, high browsing pressure was noticed in its natural stands particularly in Jaisalmer district, which limits the availability of mature seeds for their propagation and spread across region. In natural condition, it is usually found in highly browsed condition (Fig. 2b & c). However, under protected condition, its profuse flowering and fruiting was observed in most of the plants (Fig. 1a & b).

Plant Growth

In Jodhpur condition, it showed good plant growth with respect to plant height, number of branches and canopy diameter after 3rd, 6th and 12th months of planting in the field (Table 3). The plant height increased up to 171.5 cm after 12 months of planting and varied from 52-105 cm, 53-108 cm and 140-198 cm at 3rd, 6th and 12th months after planting, respectively. The number of branches per plant increased considerably up to 12th months and reaching value 47.9 branches per plant and it ranged from 2-6, 6-18 and 21-72 at 3rd, 6th and 12th months after planting, respectively. In contrast to plant height and number of branches per plant, the canopy diameter increased directly with rise in the age of plants in both north-south and east-west directions. The canopy diameter in north-south and east-west direction were ranged as 70-130 cm and 84-123 cm, 59-130 cm and 82-163 cm, 100-210 cm and 115-180 cm at 3rd, 6th and 12th months after planting, respectively. The profuse plant growth of this species in adverse climatic condition of hot arid region makes it suitable for rangelands improvement.

Individual plant characterization

Ten individual plants established in Botanical Garden of ICAR-CAZRI, Jodhpur were subjected to morphological characterization using 11 important traits and their range of variation are presented in Table 4. This study revealed the presence of considerable amount of genetic variation within the plant as high CV (%) obtained in number of raceme branch^{-1} (27.3) followed by raceme length (22.9), pod length (21.0) with least in pod width (8.1). The range values of number of branches plant^{-1}, number of raceme branch^{-1}, raceme length and pod length are as 35 to 67.0, 9.0 to 20.7, 3.7 to 9.8 cm and 11.0 to 21.0 mm with mean of 50.4, 15.7, 7.1 cm and 17.5 mm, respectively. The length variability in raceme and pods are also depicted in Figure 1d & e.

Phytochemicals

Analysis of phytochemicals in different solvent extract of leaves of *I. oblongifolia* was performed (Table 5). The ethanolic extract showed antioxidant capacity of 6.26 FRUg^{-1}. The samples showed high total phenol (mg catechol equivalent g^{-1} leaves) and total flavonoids (mg quercetin equivalent g^{-1} leaves) content as 31.44 and 29.73, respectively. The saponin and chlorophyll content (mg g^{-1} leaves) were found in the samples as 0.90 and 3.18, respectively. The presence of considerable amount of phytochemicals (total phenols, total flavonoids and total antioxidant capacity in leaves of *I. oblongifolia* promote it as a good browse species in rangelands of Indian hot arid

region especially in western Rajasthan. Previous studies on different plant parts of *I. oblongifolia* have reported a range of compounds from different phytochemical classes. The major compounds identified belonged to the flavones, flavanols, phenolic acids and phytosterols followed by other groups such as aliphatic alcohols, alkaloids, polyamines and glucosinolates (Table 6). Some of the identified phytochemicals like Indigin, Indigotin, Indirubin and Indigoferic acid are characteristic of the genus *Indigofera*. Anuradha et al. (1987b) reported that there is uniform occurrence of p-coumaric, p-OH benzoic and vanillic acids and an unknown phenolic compound 'e" of hR_f value 42/57 in all the taxa. *I. dalzellii, I. hirsuta, I. oblongifolia* and *I. prostrata* stand out in the unique possession of certain compounds. The compounds Indigoferin-A, Indigoferin-B and Indigoferin-C were also reported in the species *I. gerardiana* by Tariq et al. (2011).

Pharmacological value

I. oblongifolia is one of the important traditional medicinal plant species. It is very much used by the rural and tribals and commonly used as herbal tooth brush. Owing to its rich phytochemical profile, it exhibits various health promoting effects. Recently, Abdel Moneim (2016) reported protective, anti-fibrotic, antioxidant, and anti-apoptotic activities of *I. oblongifolia* extracts on PbAc-induced hepatotoxicity. Al-Quraishy et al. (2016) investigated the possible neuroprotective role of *I. oblongifolia* leaf methanolic extract against lead-induced neurotoxicity. It indicated its beneficial effects on mitigating lead acetate-induced neurotoxicity *via* its antioxidant and anti-apoptotic activities. Dikhil et al. (2019a) proved the antioxidant activities of *I. oblongifolia* in the spleen against the oxidative damage induced by *Trypanosoma evansi*. Dikhil et al. (2019b) investigated the impact of *I. oblongifolia* leaf extract on *Trypanosoma evansi*-induced hepatic injury. Further, Dikhil et al. (2019c) investigated the potential role of *I. oblongifolia* leaf extract on hepatic inflammation in mice with *Plasmodium chabaudi*-infected erythrocytes. They found that it exerts significant effects against malaria and protects the liver from injury caused by *P. chabaudi* via antioxidant and anti-inflammatory ways. Dikhil et al. (2020) reported that *I. oblongifolia* has anti-trypanosomal activity and might enhance the brain response to *Trypanosoma evansi*. Lubbad et al. (2015) also reported that *I. oblongifolia* leaves extract exhibits significant antimalarial and antioxidant effects, and protects host spleen tissue from injuries induced by *Plasmodium chabaudi*.

Sethi et al. (2006) explained the reasons for the anti-inflammatory and anti-cancer activities of *I. oblongifolia*. They indicated that anti-cancer and anti-inflammatory activities previously assigned to indirubin may be mediated in part through the suppression of the NF-kappaB activation pathway. Upwar et al. (2011) investigated and evaluated the anti-inflammatory effect of *I. oblongifolia* extracts on carrageenan induced inflammation in rats and provide scientific evidence for development of *I. oblongifolia* as a potential natural oral anti-inflammatory agent. Shahjahan et al. (2005) also assessed the protective effect of *I. oblongifolia* in CCl_4-induced hepato toxicity and suggest the antioxidant property of the extract. Dahot (1999) also reported anti-microbial and antifungal activity of small proteins in leaves of *I. oblongifolia*.

Conclusion

Various findings showed that species of *Indigofera* are vital important for arid and semi-arid rangelands. Rahman et al. (2018) rightly pointed out that much attention should be paid to *Indigofera* species for further discovery of novel

phytochemicals and their evaluation for pharmacological activities. Present study showed that *I. oblongifolia* is a multi-use leguminous woody perennial species in western Rajasthan and as a good source of browse to small ruminants in its range of natural distribution cover. Besides as a forage/fodder value, it can be very well exploited for its medicinal value, as the species is viewed as an antidote for all kinds of poisons and known for its analgesic and anti-inflammatory effects. The good plant growth under hot arid condition makes it suitable for introduction in alternate land use systems or in rangelands improvement programme. The presence of good amount of total phenols, total flavonoids and total antioxidant capacity in leaves revealed its suitability to promote as a browse species in rangelands of hot arid region especially in western Rajasthan. There is research need to conduct the feeding trials on small ruminants and detailed study on nutritive and also anti-nutritive factors if any for its wider use. Moreover, there is need of *in-situ* conservation of its natural stands in the region and also to create awareness amongst the inhabitants for its multi-use value.

Table 1 Passport information of collected germplasm of *I. oblongifolia* (10 accessions)

S. no.	Site of collection		Latitude °N	Longitude °E	Altitude (m)	Frequency	Habitat
	Village	District					
1.	Amarsagar	Jaisalmer	26.93	70.87	260.3	Low	Wasteland
2.	Devikot	Jaisalmer	26.71	71.19	267.0	Low-Medium	Wasteland
3.	Dabla	Jaisalmer	26.79	71.09	276.1	Low-Medium	Wasteland
4.	CAZRI RMC Jadan	Pali	25.84	73.47	233.8	Low	Scrubland
5.	Kajangarh	Pali	25.83	73.21	221.3	Low	Roadside
6.	Khurdai	Pali	25.72	73.25	222.2	Low	Roadside
7.	Ropawash	Pali	25.76	73.23	206.0	Low	Roadside
8.	Devikot	Jaisalmer	26.72	71.18	275.2	Low	Arable
9.	Dabla	Jaisalmer	26.79	71.09	272.8	Low	Wasteland
10.	Barahmsar	Jaisalmer	27.04	70.90	153.3	Low	Wasteland

Table 2 Range of variation on soil parameters collected from collection sites of *I. oblongifolia*

	pH	EC (dS m^{-1})	Av. P (kg ha^{-1})	SOC (%)	Av. K (kg ha^{-1})
Average	8.27	2.86	12.04	0.34	226.81
Minimum	7.57	0.09	1.12	0.14	67.50
Maximum	9.02	16.30	23.52	0.76	382.50

Table 3 Growth data of *I. oblongifolia* at Jodhpur, India

Plant attributes	After 3rd months planting		After 6th months planting		After 12th months planting	
	Range	Average	Range	Average	Range	Average
Plant height (cm)	52-105	74.5	53-108	77.5	140-198	171.5
No. of branches	2-6	3.3	6-18	11.1	21-72	47.9
Canopy diameter (cm)						
North-South	70-130	95.2	59-130	105.8	100-210	141.0
East-west	84-123	100.0	82-163	110.4	115-180	145.9

Table 4 Range of variation for 11 morphological traits in *I. oblongifolia*

S. no.	Traits/ Parameters	Min.	Max.	Mean± SE	SD	CV (%)
1.	Number of branches plant^{-1}	35.0	67.0	50.4±3.3	9.8	19.4
2.	Number of racemes branch^{-1}	9.0	20.7	15.7±1.4	4.3	27.3
3.	Raceme length (cm)	3.7	9.8	7.1±0.5	1.6	22.9
4.	Number of pods raceme^{-1}	25.3	40.3	31.9±1.6	4.7	14.6
5.	Number of seeds pod^{-1}	5.3	8.0	6.3±0.3	0.8	13.0
6.	Terminal leaflet length (cm)	2.5	4.2	3.1±0.2	0.5	15.6
7.	Terminal leaflet width (cm)	0.6	1.2	0.9±0.1	0.2	19.5
8.	Lateral leaflet length (cm)	1.5	2.7	2.1±0.1	0.4	17.6
9.	Lateral leaflet width (cm)	0.5	0.9	0.7±0.0	0.1	16.0
10.	Pod length (mm)	11.0	21.0	17.5±1.2	3.7	21.0
11.	Pod width (mm)	1.5	1.9	1.7±0.0	0.1	8.1

Table 5 Phytochemical constituents in the leaves of *I. oblongifolia*

S. no.	Chemical constituent	Mean
1.	Total antioxidant capacity (FRU g^{-1})	6.26
2.	Total phenols (mg g^{-1})	31.44
3.	Total flavonoids (mg g^{-1})	29.73
4.	Saponins (mg g^{-1})	0.90
5.	Chlorophyll content (mg g^{-1})	3.18

Table 6 Phytochemicals reported in different plant parts of *I. oblongifolia*

Chemical Class	Identified compounds	Plant part	Reference
Aliphatic alcohols	Psyllostearyl alcohol, Triacontanol	Stem	Lodha et al. 1990
Phytosterols	β-Sitosterol, β-Sitosterol-β-D-glucoside, β-sitosterol glucoside, Acylated (16:0) β-sitosterol glucoside	Leaves	Abdel Moneim 2016
Antho-cyanidins	Cyanidin 3-*O*-[2"-*O*-(2‴-*O*-(sinapoyl)xylosyl)glc]5-*O*-glc, Cyanidin 3-*O*-[2"-*O*-xylosyl-6"-*O*-(p-coumaroyl) glucoside]5-*O*-malonylglc)		
Flavones	Isovitexin, Luteolin 3,7'-di-*O*-glucoside, Lupinisoflavone, Apigenin-7-*O*-glucoside, Carlinoside, Luteolin, Luteolin C-6-(2" *O*-rhamnosyl)glucoside		
Flavonols	Quercetin mono-sinapoyl-di-*O*-[glucose or galactose], Quercetin-rhamnoside dimer 1, Kaempferol 3-*O*-[rhamnosylglucosylglucoside] 7-*O*-rhamnoside, 3'-Methylluteolin 6-C-glucoside, Methyl-*O*-quercetin rhamnosylglucoside		
Glucosinolates	1-Methoxy indolyl glutathione, 5-Benzoyloxypentyl glucosinolate, Indol-3-ylmethyl glucosinolate,		
Polyamines	Caffeoyl putrescine, Diferuloyl spermine,		
Alkaloids	Indigotin, Indirubin		
Phenolic acids	Vanillic acid, Hydroxycinnamic acid ester, 3-Hydroxybenzoic acid		
Alkylated xanthene	Indigin	Whole plant	Sharif et al. 2005
Fatty acids	Indigoferic acid		

Fig. 1 Field view and plant parts of *I. oblongifolia*. **(a)** Field repository at ICAR-CAZRI, Jodhpur, **(b)** Individual branch with raceme at field, **(c)** Individual branch, **(d)** Raceme, **(e)** Pods and **(f)** Seeds

Fig. 2 Natural view of *I. oblongifolia* in Jaisalmer district of western Rajasthan. **(a)** Browsing by goats, **(b)** Seed collection at Amarsagar site (Jaisalmer) –the extent of browsing pressure can be seen by the condition of shrub and their plant height, **(c)** Dense & bushy nature of stem by browsing pressure and **(d)** Good coverage of shrub at Devikot site, Jaisalmer.

References

Abdel Moneim AE (2016) *Indigofera oblongifolia* prevents lead acetate-induced hepatotoxicity, oxidative stress, fibrosis and apoptosis in rats. PLoS One 11(7):e0158965. https://doi.org/10.1371/journal.pone.0158965

Aggarwal BB, Prasad S, Reuter S, Kannappan R, Yadev VR, Park B, Kim JH, Gupta SC, Phromnoi K, Sundaram C, Chaturvedi MM, Sung B (2011) Identification of novel anti-inflammatory agents from Ayurvedic medicine for prevention of chronic diseases: "reverse pharmacology" and "bedside to bench" approach. Curr Drug Targets 12(11):1595-1653. https://doi.org/10.2174/138945011798109464

Al-Quraishy S, Dkhil MA, Ibrahim SR, Abdel Moneim AE (2016) Neuroprotective potential of *Indigofera oblongifolia* leaf methanolic extract against lead acetate-induced neurotoxicity. Neural Regen Res 11(11):1797-1803. https://doi.org/10.4103/1673-5374.194749

Anuradha SMJ, Vijay Kumar BK, Radhakrishnaiah M, Narayana LL (1987a) Chemotaxonomy of some species of *Indigofera* L. Feddes Rep 98:449-453

Anuradha SMJ, Vijay Kumar BK, Radhakrishnaiah M, Narayana LL (1987b) Chemosystematics of some species of *Indigofera*. Proc Indian Acad Sci (Plant Sci) 97(6):443-447

Benzie IF, Strain JJ (1996) The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. Anal Biochem 239(1):70-76

Bhalla NP, Dakwale JD (1978) Chemotaxonomy of *Indigofera*. J lndian Bot Soc 57:180-185

Bhandari MM (1990) Flora of the Indian desert. MPS Repros, Jodhpur

Blanke MM (1992) Determination of chlorophyll using DMSO. Vitic Enol Sci 47(1):32-35.

BSI (2022) *Indigofera oblongifolia*. Botanical survey of India, Kolkata. https://efloraIndia.gov.in. Accessed 06 April 2022

Caius JF (1989) The medicinal and poisonous legumes of India. Scientific Publishers, Jodhpur

Dahot MU (1999) Antimicrobial and antifungal activity of small protein of *Indigofera oblongifolia* leaves. J Ethnopharmacol 64(3):277-282. https://doi.org/10.1016/S0378-8741(98)00136-6

Dhir RP (1977) Western Rajasthan soils: their characteristics and properties. In: Desertification and its control. ICAR, New Delhi, pp 102-115

Dkhil MA, Abdel-Gaber R, Khalil MF, Hafiz TA, Mubaraki MA, Al-Shaebi EM, Al-Quraishy S (2019b) *Indigofera oblongifolia* as a fight against hepatic injury caused by murine trypanosomiasis. Saudi J Biol Sci 27(5):1390-1395. https://doi.org/10.1016/j.sjbs.2019.11.038

Dkhil MA, Al-Shaebi EM, Abdel-Gaber R, Al-Quraishy S (2020) Brain response after treatment of *Trypanosoma evansi*-infected mice with *Indigofera oblongifolia*. J King Saud Univ Sci 32(4):2311-2315. https://doi.org/10.1016/j.jksus.2020.03.008

Dkhil MA, Al-Shaebi EM, Al-Quraishy S (2019c) Effect of *Indigofera oblongifolia* on the hepatic oxidative status and expression of inflammatory and apoptotic genes during blood-stage murine malaria. Oxid Med Cell Longev 2019:1-7. https://doi.org/10.1155/2019/8264861

Dkhil MA, Hafiz TA, Thagfan FA, Al-Shaebi EM, Mubaraki MA, Khalil MF, Abdel-Gaber R, Al-Quraishy S (2019a) *Indigofera oblongifolia* protects against trypanosomiasis-induced spleen injury. J Infect Public Health 12(5):660-665. https://doi.org/10.1016/j.jiph.2019.03.005

Gupta RK, Gaur YD, Malhotra SP, Dutta BK (1966) Medicinal plants of the Indian arid zone. J Agric Tradit Bot Appl 13:247-288

Hiai S, Oura H, Nakajima T (1976) Color reaction of some sapogenins and saponins with vanillin and sulfuric acid. Planta Med 29(2):116–22. https://doi.org/10.1055/s-0028-1097639

Jackson ML (1973) Soil chemical analysis. Prentice Hall of India, Pvt. Ltd., New Delhi

Joshi K, Nishteswar K (2014) A review of ethnoveterinary practices associated with animal healthcare in Barda hills Gujarat, India. Pharma sci monit 5(1):118-132

Khan D, Ahmad R (1998) Effects of saline water irrigation on germination, growth and mineral distribution in *Indigofera oblongifolia* Forsk. Hamdard Med 41(4):81-93

Kirtikar KR, Basu BD (1975) Indian medicinal plants. MLS Bisherg Singh, Mahendral Pal Singh, Dehradun

Kumar BKV (1983) Systematics and anatomical studies of some south Indian species of *Indigofera* L. Dissertation, Osmania University, Hyderabad

Kumar M, Raina P, Singh SK (2020) Soil fertility appraisal for hot arid regions of Thar desert, Rajasthan, India. Ann Arid Zone 59 (1&2):51-61

Lodha V, Khan HA, Ghanim A (1990) Chemical investigation of *Indigofera oblongifolia.* Ann Arid Zone 29(3):225-226

Lubbad MY, Al-Quraishy S, Dkhil MA (2015) Antimalarial and antioxidant activities of *Indigofera oblongifolia* on *Plasmodium chabaudi*-induced spleen tissue injury in mice. Parasitol Res 114:3431-3438. https://doi.org/10.1007/s00436-015-4568-y

Mansfeld R (2001) Mansfeld's encyclopedia of agricultural and horticultural crops. Springer Science & Business Media

Marghitas LA, Dezmirean D, Laslo L, Moise A, Popescu O, Maghear O (2007) Validated method for estimation of total flavonoids in Romanian propolis. Bulletin USAMV-CN 63-64:1-2

Mishra SP, Danie M, Sabnis SD (1981) Chemotaxonomical studies on the genus *Indigofera*. JMS Univ Baroda (27&28):7-10

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US department of Agriculture, Washington, DC, pp 1-19

Pratt PF (1982) Potassium. In: Page AL, Miller RH, Keeney DR (ed) Methods of Soil Analysis, Part II Chemical and Microbiological properties. Madison, Wisconsin, USA, pp 225-246

Purohit CS, Kulloli RN (2021) *Indigofera jaisalmerica* sp. nov. (Fabaceae): a new species from Indian desert. J Asia Pac Biodivers 14:628-635. https://doi.org/10.1016/j.japb.2021.09.006

Quattrocchi U (2012) CRC world dictionary of medicinal and poisonous plants: common names, scientific names, eponyms, synonyms, and etymology. CRC Press

Rahman TU, Zeb MA, Liaqat W, Sajid M, Hussain S, Choudhary MI (2018) Phytochemistry and pharmacology of genus *Indigofera*: A review. Rec Nat Prod 12:1-13. http://doi.org/10.25135/rnp.13.16.12.585

Sethi G, Ahn KS, Sandur SK, Lin X, Chaturvedi MM, Aggarwal BB (2006) Indirubin enhances tumor necrosis factor-induced apoptosis through modulation of nuclear factor-kappa B signaling pathway. J Biol Chem 281:23425-23435. https://doi.org/10.1074/jbc.M602627200

Shahjahan M, Vani G, Shyamala Devi CS (2005) Protective effect of *Indigofera oblongifolia* in CCl_4-induced hepatotoxicity. J Med Food 8(2): 261-265. https://doi.org/10.1089/jmf.2005.8.261

Sharif A, Ahmed E, Malik A, Riaz N, Afza N, Nawaz SA, Arshad M, Shah MR, Choudhary MI (2005) Lipoxygenase inhibitory constituents from *Indigofera oblongifolia*. Arch Pharm Res 28:761–764. https://doi.org/10.1007/BF02977339

Shetty BV, Singh V (1987) Flora of Rajasthan. Botanical survey of India, Kolkata

Singh JP, Beniwal RK (2005) Wild arid legumes diversity: a hope for rehabilitation of grazing land resources in Thar desert. J Arid Legumes 2(2):258-261

Singh U, Wadhwani AM, Johri BM (1996) Dictionary of economic plants of India. ICAR, New Delhi

Singh V, Pandey RP (1998) Ethnobotany of Rajasthan, India. Scientific publishers, Jodhpur

Singleton VL, Orthofer R, Lamuela-Raventós RM (1999) Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. Meth Enzymol 299:152-178

Tariq SA, Ahmad MN, Obaidullah, Khan A, Choudhary MI, Ahmad W, Ahmad M (2011) Urease inhibitors from *Indigofera gerardiana* Wall. J Enzyme Inhib Med Chem 26(4):480-484. https://doi.org/10.3109/14756366.2010.528415

Upwar N, Patel R, Waseem N, Mahobia NK (2011) Anti-inflammatory potential of alcoholic extract of *Indigofera oblongifolia* Forsk. Int J Res Pharm Sci 2(1):23-25

Walkley A, Black IA (1934) An examination of Degtjareff methods for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci 37:29-38

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Conflict of interest

The authors declare that they have no conflict of interest.

Statements and Declarations

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Author(s) contributions

J P Singh, Venkatesan K and Anil Patidar conceptualized the study and recorded plant growth, morphological and traditional utilization data. Mahesh Kumar analysed soil samples for different parameters. Saurabh Swami and Mahesh Kumar performed phytochemical analysis of leaves samples. J P Singh, Venkatesan K and Anil Patidar wrote and prepared the original draft and finalized the manuscript. N V Patil and Saranya R reviewed and edited the manuscript. All authors contributed to the article and approved the final manuscript.