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Two-leaf Nightshade (*Solanum diphyllum* L.)–An Addition to the Flora of Delhi, India and Weed Risk Assessment of the Species

Anjula Pandey*, K Pradheep and Rita Gupta
Division of Plant Exploration and Germplasm Collection, ICAR-National Bureau of Plant Genetic Resources, New Delhi–110012, India

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Solanum diphyllum L. (the two-leaf nightshade) is reported as a new record for flora of Delhi. Study of natural populations of the species and weed risk assessment supported it's tendency of widespread naturalization. Plant characters such as high fruit-bearing and high seed number per fruit, perennating root stock, high germination rate, seed dormancy, no natural predators (animal toxicity) and dispersal through movement of soil were the main parameters favouring fast spread of the species. A detailed description of the species along with distribution, propagation and dispersal has been discussed.

Key Words: Delhi, Flora, *Solanum diphyllum* L., Two-leaf Nightshade, Weed Risk Analysis

Introduction

Two-leaf nightshade or twin leaved nightshade (*Solanum diphyllum* L.), a native species from South Mexico to Costa Rica in Central America, was introduced as a garden plant in different continents across the world. It escaped from cultivation and widely naturalized in many tropical and subtropical regions of the world. This species belongs to the family Solanaceae, subfamily Solanoideae and tribe Solaneae (Zhang *et al.,* 1999). It is widely cultivated as an ornamental plant for clusters of dark green globose berries that turn beautiful bright yellow or reddish yellow when ripe. Most parts of the plant are very poisonous, including the leaves and berries (http://lee.ifas.ufl.edu/Hort/GardenPubsAZ/Two-leaf_Nightshade.pdf). This species has ethnomedicinal value in Tamil Nadu and Kerala (Devi Prasad and Shyma, 2013; Anilkumar *et al.*, 2014; Shalini *et al.*, 2014) and has potential medicinal value against varieties of carcinoma (Fatma *et al.*, 2010). It is also reported for ornamental value in gardens of India (https://groups.google.com/forum/?hl=en#!topic/indiantreepix/5JSz2_GU7a0;www.flowersofindia.net/catalog/slides/Twoleaf%20Nightshade.html).

During an educational trip to Herbal Garden, Punjabi Bagh, New Delhi in the month of September in 2014, the authors came across this species. A detailed examination of the characters has helped in its identification as *Solanum diphyllum* L. Critical examination and perusal of literature revealed that this species was not reported in floristic records of Delhi and adjoining areas. During subsequent visits in year 2015 and 2016, plant populations colonized new areas within garden; were also observed to be escaping beyond the garden boundaries.

In this paper, occurrence of *S. diphyllum* as a new floristic record in Delhi, along with its occasional use as an ornamental species has been reported. Keeping in view it's high weedy potential, fast spreading rate and occurrence reported from diverse states of India (Devi Prasad and Shyma, 2013; Reema Kumari, 2004, 2013; Anilkumar *et al*., 2014; Singh *et al.*, 2014; Singh *et al*., 2014; Singh and Garg, 2015; Singh and Singh, 2015), weed risk analysis was based on observations undertaken during 2014-16 at the reported site using standard method (Singh *et al*., 2013). A detailed description, distribution, propagation and dispersal is included in the present communication to facilitate easy identification and further research pertaining to plant genetic resource management.

Botany

Solanum diphyllum L., Sp. Pl. 184. 1753; D'Arcy in Ann. Missouri Bot. Gard. 61: 845. 1974; Zhi Y. Zhang *et al*. in C.Y. Wu and P.H. Raven, Fl. China 17: 317. 1994; M. Das *et al.,* J. Econ. Taxon. Bot. 21: 158. 1997; T.K. Paul and M.C. Biswas in Bull. Bot. Surv. India 37: 137. 1995. M. Reema Kumari in Rheedea 23(1) 50-51. 2013; *Pseudocapsicum diphyllum* (L.) Medik., Philos. Bot. (Medikus) 1: 122. 1789.

**Author for Correspondence: Email- anjula.pandey@icar.gov.in*

Fig. 1. *Solanum diphyllum* L. (the two-leaf nightshade) in Herbal Garden, Punjabi Bagh, New Delhi: (top row- from left to right) immature fruits in cluster; mature orange yellow berries; (bottom row- from left to right) new plants growing in waste areas; herbarium specimen deposited in National Herbarium of Cultivated Plants (NHCP) (HS22401; collector: AP, RG-28/2016)

Flowering/ fruiting: March-August; Fruiting: May-November (in Delhi).

Plant is a herbaceous-woody perennial, small shrub of about 1-2.4 m height, smooth stem with brown bark; leaves- leathery, glossy, dark green on the upper surface, light green on the ventral surface, born in pairs from a single bud, one is large and elliptic-obovate, size 6×2 cm, the other smaller and rounded, size 2×1 cm; petiole 2 mm; inflorescences bearing 5-23 tiny drooping white flowers of 1 cm diameter borne in leaf axils. Each flower has five recurved petals of lavender tinge and stamens with large yellow anthers. The fruits are berries, spherical, smooth with a slight division around the middle, especially when unripe, green and hard when young, around 0.9-1 cm, mature into bright yellow to yellow orange. Each fleshy fruit has 30-45 seeds, about 1-1.5 mm, flattened, creamish-light brown, kidney-shaped with undulating surface (Fig.1).

Distribution

The two-leaf nightshade was in cultivation in the 1960's as an ornamental plant in subtropical and tropical parts of the world. Later it was spotted as a "bird-dispersed" volunteer in hedges and pastures in South Florida in the late 1960's, and reported as a "widespread escape" by 1967. Presently it is naturalised in diverse habitats of South and Central Florida (http://lee.ifas.ufl.edu/Hort/GardenPubsAZ/Two-leaf_Nightshade.pdf).

The first report on occurrence of two-leaf nightshade in India was published in the year 1995 with only a few individual plants growing at two locations in Howrah district of West Bengal (Paul and Biswas, 1995) and later reconfirmed (Das *et al*., 1997). In 2006, the species was recorded to be widespread, occupying grasslands and forests edges in Lonavala and Khandala and other wastelands of Pune, Pimpri-Chinchwad and neighbouring towns of Maharashtra. Its occurrence was reported in

various botanical gardens of Pune including the Empress Garden, Mudwa Experimental Garden of Botanical Survey of India (BSI), the associated garden of BSI office campus and other public gardens (Singh *et al*., 2014).

Subsequent reports of occurrence of species as a new record for North-eastern India (Assam) (Nath *et al*., 2010), Maharashtra (Pune and Powai), Karnataka (Bengaluru) and for southern India (Reema Kumari, 2004, 2013; http://indiabiodiversity.org/observation/show/378847), Bihar (Bhagalpur district) (Halder *et al*., 2013; Annual Report, 2013), Tamil Nadu (Shalini *et al*., 2014), Kerala (Wayanad and Periyar districts) (Devi Prasad and Shyma, 2013; Anilkumar *et al*., 2014), Uttar Pradesh (Varanasi, Mirzapur and Sonebhadra districts) (Singh and Singh, 2015) and scattered reports from various parts of India (Rajkumar Singh *et al.*, 2014) indicated its fast spread to different parts of the country. Singh and Garg (2015) have reported its spread to four northern states viz., Bihar [(West Champaran district), Chhattisgarh (Koriya district)], Madhya Pradesh (Anuppur district) and Uttar Pradesh (Allahabad, Gorakhpur and Varanasi districts) and Eastern Ghats (Kalahandi region, Koraput district, Odisha) (Murugan *et al*., 2015; Sahu *et al*., 2015) suggesting the spread mainly through plant nurseries as primary source. Report on widespread occurence of species in the entire Acharya Jagadish Chandra Bose Indian Botanic Garden, BSI, Howrah justified its categorization as a "serious weed" posing a suspected threat to many endemic species (Singh *et al*., 2014). Deliberate introduction of the species in various gardens and pattern of spread to neighbouring areas through dispersal by various means has been evidently reflected through author's observations and various published records.

During the collection of germplasm by the second author to Vishakhapatnam district, Andhra Pradesh in 2015, it was also observed that there were naturalized population of the species (K Pradheep/Babu Abraham-2083; HS22157; 31.10.2015).

The authors noted the occurrence of *S. diphyllum* in Delhi for the first time at the Herbal Garden, Punjabi Bagh (Horticulture Department, Delhi Nagar Nigam) in 2014 along the boundary wall represented by a few individual plants (one year-old plants). These were growing with the grasses, *Coccinia grandis*, *Convolvulus arvense, Abutilon indicum*, *Chenopodium album*, etc. Subsequent observations during September-November in 2015 and 2016 by the authors indicated fast spread of populations from original location towards central side of garden area and also outside the garden premises on road side. Personal communication with garden authorities indicated it's planting as an ornamental long back. During study, the authors observed weedy populations occurring in different parts of the garden (Fig. 1).

The authors observed plants only under self-sown state in different populations in the Herbal Garden, Punjabi Bagh, Delhi. Intermittent occurence of plants with other cultivated species growing in garden and pattern of spread also supported its dispersal through seed movement along with the soil clods. *Solanum diphyllum* is also known by the local name '*pili makoe*' (makoi is common name used in northern India for *S. nigrum*). This species was not recorded from floristic literature of Delhi and adjoining region (Clarke, 1883; Duthie, 1960; Maheshwari, 1963; Mishra, 2015) nor was it recorded for any use (Ambasta *et al*., 1986) except for deliberate introduction as an ornamental plant. However, the species is also reported to be planted in some gardens of Delhi (Green Park area, Herbal Garden, Punjabi Bagh, Delhi and Old Delhi Ridge) (https://sites.google.com/site/efloraofindia/species/m---z/s/solanaceae/solanum/solanum-diphyllum; http://indiabiodiversity.org/biodiv/species/show/231159). Hence, it forms the first floristic record of Flora of Delhi. Flowering and fruiting specimens were collected and seeds were deposited in the National Herbarium of Cultivated Plants (NHCP) (HS22381, 22401, 22405 and 22464; Seed Sample no.3070).

Propagation and Seed Germination

Solanum diphyllum propagates through seeds and 30-45 seeds/berry were recorded. A three-four year old plant produced at least 2000-2500 seeds in a growing season. It was observed that mature plants dry with dormant rootstock in December-January but resprout in March.

Seeds from mature berries were extracted, dried and subjected to seed germination study. Seed germination was upto 100% using GA_3 treatment (using moist filter paper) (pers. comn. Dr J Radhamani, ICAR-NBPGR). Studies have indicated that seed can stay alive in soil even when buried an inch in the soil for up to two years; seeds can sustain drought stress but are sensitive to high salinity induced by NaCl (Mohamed *et al*., 2010). Studied populations showed seed spread/dispersal through mechanical means (movement of

the soil clods, irrigated water) in the garden or man managed areas where there was movement of the dried fruits from one place to another. However, according to reports available in literature, seeds are mainly dispersed by the birds (Galindo-gonzález *et al*., 2000; Singh and Garg, 2015).

Weed Risk Analysis

Many garden plants of exotic origin pose a high risk of naturalization and potential as a weed in the area of cultivation (Groves *et al*., 2005; Pandey *et al*., 2015). Two-leaf nightshade with reports of invasiveness in many countries (http://fnai.org/Invasives/Solanum_diphyllum_FNAI.pdf) coupled with high drought tolerance poses risk of it's escape from gardens and establishment as a naturalized population.

Among many introduced garden plants under cultivation, the two-leaf nightshade is naturalized in parts of India. Keeping this in view, weed risk assessment was done based on standard procedure (Singh *et al*., 2013). This information provides status of evasiveness of the species based on biological and ecological parameters. Species was subjected to weed risk assessment system based on a question-based scoring containing 49 questions. The response to the questions generated a numerical score with positive correlation to the weediness (Annexure 1). The score of '15' out of 49 for this species revealed its potential as "serious weed" in cultivable/ agricultural land. Traits such as high-fruit bearing and high seed number/fruit, perennating rootstock, high germination rate, seed dormancy, no natural predators (animal toxicity) and dispersal through movement of soil were mainly observed to influence fast spread of the species.

Information on new record of this species to flora of Delhi may add new distribution range for the region. Besides, it's spread as a weed in areas of cultivation as studied through visual observations and weed risk analysis, it will add to the knowledge regarding risk of fast naturalization through escaping from cultivation.

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Annexure 1

Weed Risk Assessment Questionnaire for *Solanum diphyllum*

Botanical name:			*Solanum diphyllum*	Outcome:	Reject
Common name:			Two leaved night shade	Score:	15
Family name			Solanaceae	Your name: Dr. Anjula Pandey	
History/Biogeography					
A	1	Domestication/	1.01	Is the species highly domesticated. If answer is 'no' go to question 2.01	n
C		Cultivation	1.02	Has the species become naturalized where grown	y
C			1.03	Does the species have weedy races	y?
	2	Climate	2.01	Species suited to Indian climates (0-low; 1-intermediate; 2-high)	1
		Distribution	2.02	Quality of climate match data (0-low; 1-intermediate; 2-high)	1
C			2.03	Broad climate suitability	
C			2.04	Native or naturalized in regions with extended dry periods	n
			2.05	Does the species have a history of repeated introductions outside its natural range	n
C	3	Weed	3.01	Naturalized beyond native range	y
E		elsewhere	3.02	Garden/amenity/disturbance weed	garden
A			3.03	Weed of agriculture/horticulture/forestry	Weed of horticulture ?
E			3.04	Environmental weed	y
			3.05	Congeneric weed	
Biology/ Ecology					
A	4	Undesirable	4.01	Produces spines, thorns or burrs	n
C		traits	4.02	Allelopathic	
C			4.03	Parasitic	
A			4.04	Unpalatable to grazing animals	y
C			4.05	Toxic to animals	y (eaten by birds)
C			4.06	Host for recognised pests and pathogens	?
C			4.07	Causes allergies or is otherwise toxic to humans	y
E			4.08	Creates a fire hazard in natural ecosystems	n
E			4.09	Is a shade tolerant plant at some stage of its life cycle	y
E			4.10	Grows on infertile soils	n
E			4.11	Climbing or smothering growth habit	
E			4.12	Forms dense thickets	
E	5	Plant type	5.01	Aquatic	
C			5.02	Grass	
E			5.03	Nitrogen fixing woody plant	
C			5.04	Geophyte	
C	6	Reproduction	6.01	Evidence of substantial reproductive failure in native habitat	
C			6.02	Produces viable seed	y
C			6.03	Hybridises naturally	
C			6.04	Self-fertilisation	
C			6.05	Requires specialist pollinators	
C			6.06	Reproduction by vegetative propagation	n
C			6.07	Minimum generative time (years)	
A	7	Dispersal	7.01	Propagules likely to be dispersed unintentionally	y
C		mechanisms	7.02	Propagules dispersed intentionally by people	
A			7.03	Propagules likely to disperse as a produce contaminant	y
C			7.04	Propagules adapted to wind dispersal	n
E			7.05	Propagules have dormancy	y
E			7.06	Propagules bird dispersed	y
C			7.07	Propagules dispersed by other animals (externally)	n?
C			7.08	Propagules dispersed by other animals (internally)	?
C	8	Persistence	8.01	Prolific seed production	y
A		attributes	8.02	Evidence that a persistent propagule bank is formed (>1 yr)	y
A			8.03	Well controlled by herbicides	
C			8.04	Tolerates or benefits from mutilation, cultivation or fire	
E			8.05	Effective natural enemies present in India	

A=agricultural, E= environmental, C=combined; Total score - 15