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Apiospora vs. *Arthrinium*: Taxonomic Status of Indian Species with Special Reference to Their Host Range and Distribution in India

Sayantan Jash[1] and Rashmi Dubey[1]*

[1]*Botanical Survey of India, Western Regional Centre, 7 Koregaon Road, Pune - 411 001, Maharashtra, India.*

**Corresponding author Email: dr.rashmidubey@gmail.com*

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ABSTRACT

***Apiospora* and Arthrinium do not seem to have clear diagnostic morphological features but in a mordern studies, the combination of morphological, genetic, and ecological characteristics suggested that *Apiospora* and *Arthrinium* represent independent lineages within *Apiospora*ceae and thus should be considered as different genera. As per previously published literature, four species of *Apiospora* and nineteen species of *Arthrinium* were reported from India based on their morphological characters. But recently, based on polyphasic approach, a huge number of Indian *Arthrinium* species have been transferred to the genus *Apiospora* and currently only four Indian species exist under the genus *Arthrinium*. Therefore, in order to provide a comprehensive data of Indian *Apiospora* and Arthrinium, a thorough study was conducted based on field survey, literature review and phylogenetic analysis of deposited published sequences. The recent study deals with the current taxonomic status of Indian species of *Apiospora* and *Arthrinium* along with their comparative morphological account, host range and distribution.**

Keywords: *Apiospora*ceae, Comparative morphology, Host families, nr-ITS, Polyphasic approach

INTRODUCTION

The genus *Arthrinium* was proposed by Kunze & Schmidt (1817) and validated by Fries (1832) with the type species *Ar. caricicola*. Species of *Arthrinium* are commonly found in temperate, cold, or alpine regions, mainly growing on Cyperaceae and Juncaceae hosts, but some are also reported on Poaceae (Pintos and Alvarado, 2021). On the other side, *Apiospora* was introduced by Saccardo in 1875 with *Ap. montagnei* as type species (Saccardo, 1875). *Apiospora* is a cosmopolitan fungus, reported from various sources such as plants, soil, air, and marine samples in tropical, subtropical, temperate, and even cold regions. Moreover, they have been characterized as endophytes, saprobes, and plant pathogens, especially in Poaceae (Pintos and Alvarado, 2021). A biological relationship between *Apiospora* (telomorphic stage) and *Arthrinium* (anamorphic stage) has been well established and widely accepted for a long time (Ellis, 1965). Later, Crous and Groenewald (2013) synonymized *Apiospora* with *Arthrinium*, granting priority to *Arthrinium* based on the one fungus, one name policy (Hawksworth *et al.*, 2011). Morphologically *Apiospora* and *Arthrinium* do not seem to have clear diagnostic features, but in a modern study, the combination of morphological, genetic, and ecological characteristics suggested that *Apiospora* and *Arthrinium* represent independent lineages within *Apiospora*ceae and thus should be considered as different genera (Pintos and Alvarado, 2021). Worldwide 120 epithets of *Arthrinium* have been listed in Index Fungorum (2025), among which most are being transferred to the genus *Apiospora*, whereas the genus *Apiospora* consists of 202 epithets (Index Fungorum 2025).

As per previously published literature, four species of *Apiospora* and nineteen species of *Arthrinium* were reported from India based on their morphological characters (Butler and Bisby, 1931; Sarbhoy *et al.*, 1981; Bilgrami *et al.*, 1991; Jamaluddin *et al.*, 2004; Manoharachary *et al.*, 2022). Recently, a huge number of Indian *Arthrinium* species have been transferred to the genus *Apiospora* based on polyphasic approach (Pintos and Alvarado, 2021). Therefore, a study was conducted to assess the current taxonomic status of the Indian species of *Apiospora* and *Arthrinium* along with their comparative morphological accounts, host range and distribution.

MATERIALS AND METHODS

Along with field exercise, different volumes of Fungi of India (Butler and Bisby, 1931; Sarbhoy *et al.*, 1981; Bilgrami *et al.*, 1991; Jamaluddin *et al.*, 2004; Manoharachary *et al.*, 2022) and a few other pieces of literature (Bhat and Kendrick, 1993; Hande *et al.*, 2014; Sharma *et al.*, 2014; Rana *et al.*,

2017; Dubey and Pandey, 2022, 2023; Hafeez *et al.*, 2023) have been surveyed thoroughly for making a comprehensive list of Indian species of *Apiospora* and *Arthrinium* along with their distribution and hosts. A phylogenetic analysis has been conducted to verify the current status of the species of *Apiospora* and *Arthrinium* reported from India. For this purpose, sequence data of species reported from India were retrieved from NCBI GenBank (https://www.ncbi.nlm.nih.gov/) based on previously published authentic literature. A thorough phylogenetic analysis was performed following a standard protocol (Pintos and Alvarado, 2021). The distribution map of the Indian species of *Apiospora*, *Arthrinium* and *Neoarthrinium* has also been presented with the help of ArcMap 10.2.2 by incorporating GPS Data of the localities.

RESULTS

Phylogenetic analysis

In this study, a total of 23 sequences of *Apiospora*, *Arthrinium* and *Neoarthrinium* including one sequence i.e. *Apiospora neobambusae* generated by author have been selected for the phylogenetic analysis, and *Seiridium phylicae* (CBS H-21089) as the outgroup taxon. In the phylogenetic analysis, the final alignment consisted of 664 characters in total, including gaps. The RAxML analysis of the combined dataset yielded the best scoring tree (Figure 1) with a final ML optimization likelihood value of -3472.769922. The matrix had 300 distinct alignment patterns, with 15.17% undetermined characters or gaps. The estimated base frequencies were as follows: A = 0.267407, C = 0.265230, G = 0.236189, and T = 0.231174; substitution rates AC = 0.633766, AG = 1.124538, AT = 1.072259, CG = 0.929752, CT = 2.806836, and GT = 1.000000; and gamma distribution shape parameter α = 0.582267.

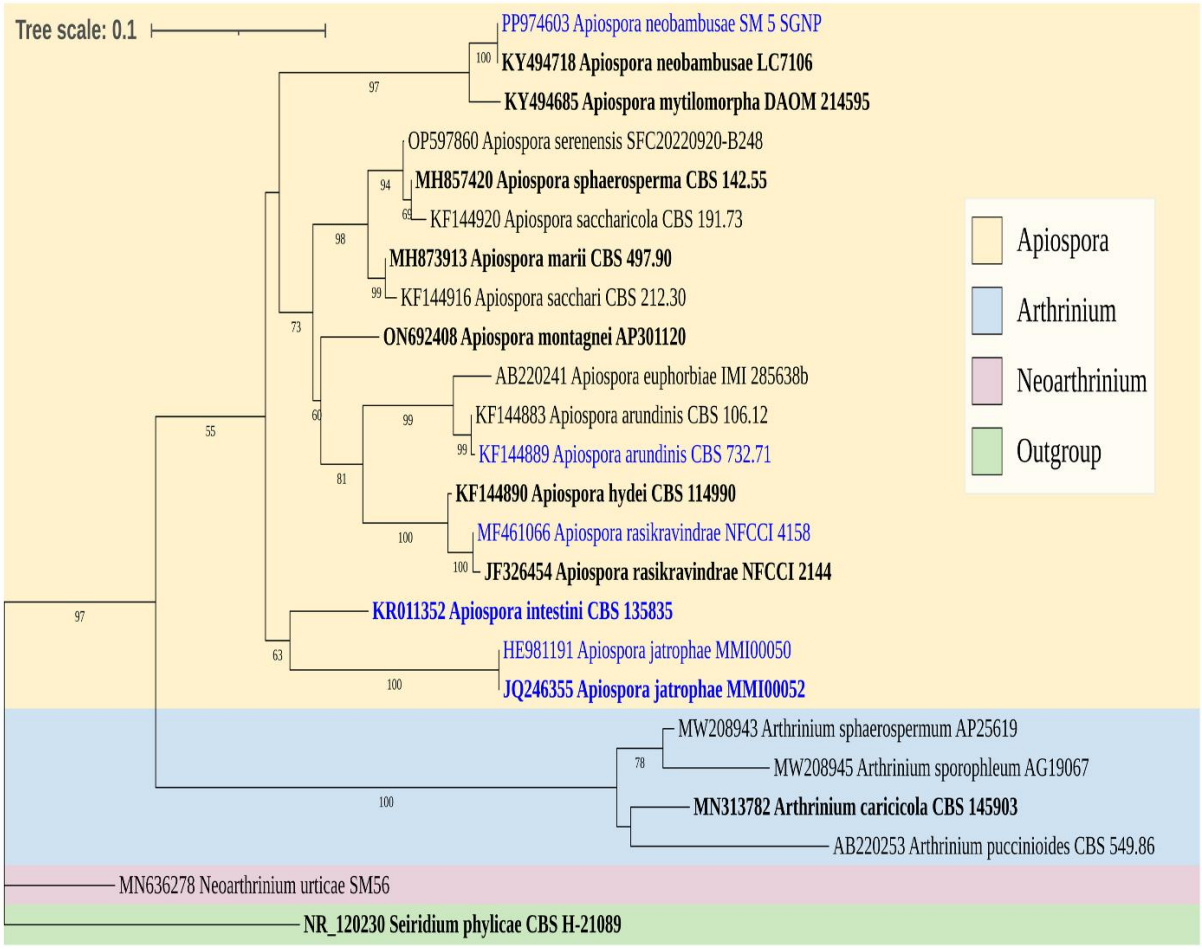

Figure 1: Phylogram generated by maximum likelihood analysis based on ITS sequence data for species of *Apiospora*, *Arthrinium*, and *Neoarthrinium* reported from India. Maximum likelihood bootstrap support values (MLbs) ≥50% are shown. Type sequences are placed in bold and sequences from Indian accessions are placed in blue font, respectively, to highlight their phylogenetic positions in the tree.

Furthermore, according to the phylogenetic results, two different clades of *Apiospora* and *Arthrinium* have been differentiated with very strong Maximum Likelihood Bootstrap Support (97%). Individually both the clades containing type species of each genus also have very good support (55% in the clade of *Apiospora* and 100% in the clade of *Arthrinium*). Indian accessions of *Apiospora* spp. are showing strong bootstrap support with type sequences and other published uthentic sequences. The placement of the genus *Neoarthrinium* inside the family *Apiospora*ceae is doubtful as it is creating polytomy.

Taxonomy

***Apiospora*ceae** K.D. Hyde, J. Fröhl., Joanne E. Taylor & M.E. Barr

Sexual Morph: Ascomata immersed or semi-immersed, visible on the host surface as raised, blackened areas, gregarious; in vertical section globose, longitudinal axis vertical to the host surface, papillate, periphysate. Peridium comprising elongate, isodiametric, mostly brown-walled cells. Paraphyses hypha-like. Asci 8-spored, clavate, thin-walled, apically rounded, lacking any apical apparatus. Ascospores overlapping uniseriate or biseriate, hyaline, apiosporous and smooth-walled, possibly with appendages or sheaths.

Asexual Morph: Colonies compact or widely effused, black or dark blackish brown, fructifications occasionally erumpent but usually superficial and frequently pulvinate. Mycelium partly superficial, partly immersed, often with connecting hyphae which become very narrow where they pass through the host cuticle. Stroma none. Setae and hyphopodia absent. Conidiophores basauxic, macronematous, mononematous, arising singly from subspherical, ampulliform, barrel-shaped or broadly clavate conidiophore mother cells, simple, often narrow, more or less cylindrical, usually colourless except for the thick transverse septa which may be highly refractive and are often brown or dark brown. Conidiogenous cells integrated, terminal and intercalary, polyblastic, denticulate, pegs usually very short, cylindrical, truncate. Conidia solitary, lateral and sometimes also terminal, distinctively shaped, frequently flattened and with a hyaline rim or germ slit, brown or dark brown, smooth, aseptate. Sterile cells when present terminal or sub terminal in place of conidia, usually smaller, paler and not the same shape as conidia, often containing 1 or more highly refractive cubical bodies.

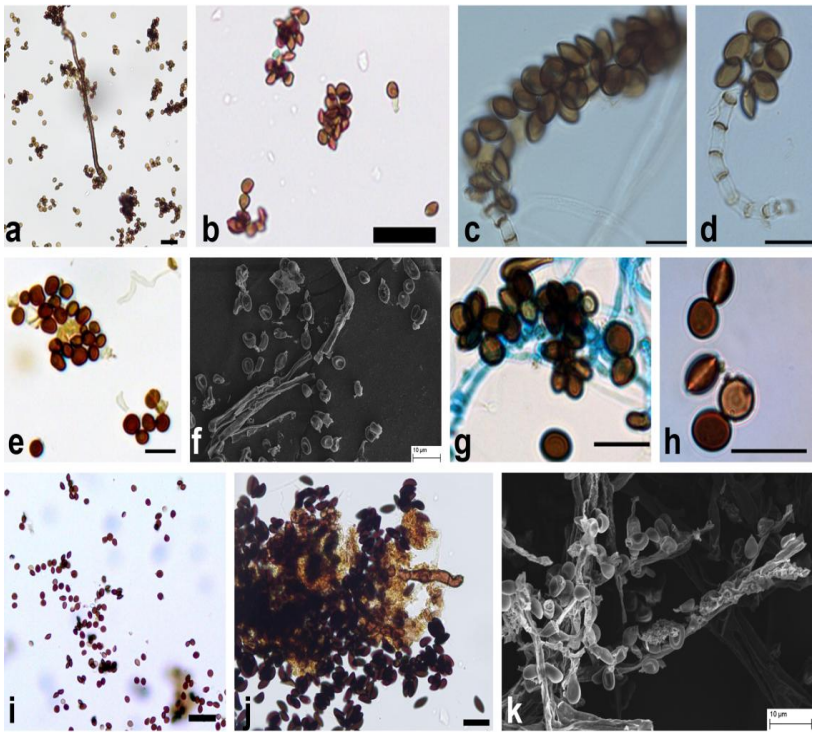

Figure 2: Species of *Apiospora* and *Arthrinium* reported from India. a – b, *Apiospora euphorbiae* (© Dubey and Pandey, 2023); c – d, *Apiospora jatrophae* (© Sharma *et al.*, 2014); e – f, *Apiospora neobambusae* (© Dubey and Pandey, 2023); g – h, *Apiospora rasikravindrae* (© Rana *et al.*, 2017); i, *Apiospora sacchari* (© Dubey and Pandey, 2023); j – k, *Arthrinium sporophlaeum* (© Dubey and Pandey, 2023). Scale bars: a - d, g - j = 20 µm; e - f, k = 10 µm.

Table 1: Comparative morphological account, distribution, and host range of Indian species of *Arthrinium* and *Apiospora* along with their current taxonomic status

Currently Accepted name of fungus	Previous names of Indian species as per different literatures	Asexual morph				Sexual morph				Distribution in India	Host	References
		Size of Conidiomata/ Colonies	Size of Conidioph-ores	Size of Conidia	Other Special Characters	Size of Ascostroma	Size of Ascus	Size of Ascospore	Other Special character			
Apiospora arund inis (Corda) Pintos & P. Alvarado	*Arthrinium arundinis* (Corda) Dyko & B. Sutton	-	4-50 µm × 0.5 µm	5.5-8 × 3-4.5 µm	Conidia lenticular, pale to mid-brown, bilaterally flattened with a hyaline band at the junction of the two sides	Unknown				INDIA (Location not mentioned)	Dung	Crous and Groenewald, 2013
Apiospora camp tospora Penz. & Sacc.	*Apiospora camptospora* Penz. & Sacc.	Unknown				180 - 200 µm diam.	75 - 80 × 15 - 17 µm	35 - 38 × 9 µm	Ascospores cylindrical to oblong, curved downwards , obtuse on both sides, below the middle 1-septate, not constricted	MAHARASHTRA (Manjri)	Poaceae (Maize)	Jamaluddin *et al.*, 2004
Apiospora euph orbiae (M.B. Ellis) X.G. Tian & Tibpromma	*Arthrinium euphorbiae* M.B. Ellis	-	15–110 × 0.5–1 µm	4–5.5 µm diam. in face view, 3–4 (3.2) µm thick	Conidia lenticular, brown or olivaceous brown, smooth-walled	Unknown				TAMIL NADU (Kolli Hills); MAHARASHTRA (Harisal, Mumbai)	Leaf litter; Poaceae	Dubey and Pandey, 2023; Jamaluddin *et al.* 2004; Manoharachary *et al.*, 2022
Apiospora hydei (Crous) Pintos & P. Alvarado	*Arthrinium hydei* Crous	-	20–40 × 3–5 µm	(15–)17–19(–22) µm diam in surface view, (10–)11–12(–14) µm diam in side view	Conidia brown, roughened, globose in surface view, lenticular in side view, with pale equatorial slit	Unknown				MAHARASHTRA (Melghat Forest)	Poaceae (*Bambusa* sp.)	Hande *et al.*, 2014
Apiospora indic a Theiss. & Syd.	*Apiospora indica* Theiss . & Syd.	Unknown				1 - 1.5 mm long, 180 - 240 µm wide	75 - 100 × 18 - 24 µm	22 - 27 µm long (lower cell 5 - 10 µm long), 7 - 9 µm wide	Ascospores somewhat club-shaped, not or barely constricted at the septum. Paraphyses absent.	ASSAM (Nangki Hills); UTTARAKHAND (Dehradun); KERALA (Wynaad)	Poaceae (*Bambusa* sp.)	Bilgrami *et al.*, 1991; Butler and Bisby, 1931

Apiospora intestini (Kajale, Sonawane & Roh. Sharma) Pintos & P. Alvarado	*Arthrinium intestini* Kajale, Sonawane & Roh. Sharma [as '*gutiae*']	-	21.5–50 × 2–2.5 µm	(4.5–)5.5(–6) µm diam in surface view, (2–)4(–6) µm diam in side view	Conidia borne as bunches on conidiophores, lateral and terminal, brown, smooth, aseptate, globose in surface view, lenticular in side view, with pale equatorial slit	Unknown		MAHARASHTRA (Pune)	Gut of Insect	Crous *et al.*, 2015
Apiospora jatrophae (Rohit Sharma) Pintos & P. Alvarado	*Arthrinium jatrophae* Rohit Sharma	-	49.1 - 88.6 × 2.7 - 6.5 (mean 68.5×5.3) µm	6.5 - 9.7 (mean 8.4) µm in face view and 3.2 - 6.5 (mean 4.3) µm in side view	Some anomalous conidia are also produced which are elongated, smooth, brown, tapering at one end	Unknown		MAHARASHTRA (Pune)	Euphorbiaceae (*Jatropha podagrica*)	Sharma *et al.*, 2014
Apiospora marii (Larrondo & Calvo) Pintos & P. Alvarado	*Arthrinium marii* Larrondo & Calvo	-		7.2-7.5 × 6.1-6.5 µm	Conidia solitary. lateral or terminal, usually dark brown with a distinct hyaline rim	Unknown		MAHARASHTRA (Melghat Forest)	Poaceae (*Bambusa* sp.)	Hande *et al.*, 2014
Apiospora montagnei Sacc.	*Apiospora montagnei* Sacc.	-	(10–)18–34(–45) × (1.5–)1.6–1.8(–2) µm	(9–)10.3–11.3(–12) µm in surface view, (5–)6.2–7.2(–8) µm in side view	Conidia smooth to finely roughened, with an equatorial germ slit of paler pigment. Sterile cells ellipsoidal to clavate.	Unknown		WEST BENGAL (Darjeeling); KARNATAKA (Mysore); MAHARASHTRA (Kamthe, Ratnagiri); KERALA (Idamalayar); ASSAM (Diphu, Golaghat)	Poaceae (*Arundinaria* sp., *Bambusa* sp., *Ochlandra travancorica*)	Bilgrami *et al.*, 1991; Sarbhoy *et al.*, 1981
Apiospora mytilomorpha (Bhat & W.B. Kendr.) Pintos & P. Alvarado	*Arthrinium mytilomorphum* Bhat & W.B. Kendr.	-	up to 80 µm × 4.5 - 5 µm	20 - 30 × 6 - 8.5 µm	Conidia solitary, dry, fusiform to navicular, slightly curved and asymmetrical, non-septate (amerosporous), smooth-walled, broadest in the middle, tapering toward the narrowly rounded ends	Unknown		KARNATAKA (Kodachadri Hills)	Poaceae (*Andropogon* sp.)	Bhat and Kendrick, 1993
Apiospora neobambusae Pintos & P. Alvarado	*Arthrinium bambusae* Mei Wang & L. Cai	-	reduced to conidiogenous cells, 4.0–12.0 × 3.0–7.0 µm	11.5–15.5 × 7.0–14.0 µm	Conidia olivaceous to brown, smooth to finely roughened, subglobose to ellipsoid	Unknown		MAHARASHTRA (Palghar)	Dead twig	Dubey and Pandey, 2023
Apiospora rasikravindrae (Shiv M. Singh, L.S. Yadav, P.N. Singh, Rah. Sharma & S.K. Singh) Pintos & P. Alvarado	*Arthrinium rasikravindrae* Shiv M. Singh, L.S. Yadav, P.N. Singh, Rah. Sharma & S.K. Singh [as '*rasikravindrii*']	-	5 - 90 × 1 - 1.5 µm	10 - 15 × 6.0 - 10.5 µm in face view	Conidia dimorphous, smooth, double-walled, brown to pale olivaceous with prominent truncate base and equatorial germ slit	Unknown		HIMACHAL PRADESH (Simbal)	Solanaceae (*Capsicum* sp.)	Rana *et al.*, 2017

Apiospora rhodophila Sacc.	*Apiospora rhodophila* Sacc.	Unknown				0.3-0.5 mm. diam.	80-120 × 15-16 µm	18-22 × 7-8 µm	Ascospores 1-septate near the base, not constricted, hyalin, at the bottom hardly 5 µm long	UTTAR PRADESH (Garwal)	Rosaceae (*Rosa macrophylla*)	Bilgrami *et al.*, 1991; Butler and Bisby, 1931
Apiospora sacchari (Speg.) Pintos & P. Alvarado	*Arthrinium sacchari* (Speg.) M.B. Ellis	-	Conidiophores reduced to conidiogenous cells	(6-)7(-8) µm diam in face view, (3.5-)4 µm diam in side view	Conidia brown, smooth, granular, globose in surface view, lenticular in side view, with pale equatorial slit, with central basal scar	Unknown				MAHARASHTRA (Thane, Poona); KERALA (Idamalayar); MADHYA PRADESH (Jabalpur)	Dead twig; Poaceae (*Cynodon dactylon*, *Bambusa* sp., *Ochlandra travancorica*)	Bilgrami *et al.*, 1991; Dubey and Pandey, 2022; Jamaluddin *et al.*, 2004
Apiospora saccharicola (F. Stevens) Pintos & P. Alvarado	*Arthrinium saccharicola* F. Stevens	-	Conidiophores reduced to conidiogenous cells	(7-)8 - 9(-10) µm diam in face view, (4-)5(-6) µm diam in side view	Conidia brown, smooth, granular, globose to ellipsoid in surface view, lenticular in side view, with pale equatorial slit (at times appearing like a ridge of paler pigment)	Unknown				TAMIL NADU (Thantipandal, Kambakkam, Chingelput); BIHAR (Patna); ASSAM (Diphu, Guwahati)	Poaceae (*Andropogon sorghum*, *Bambusa* sp., Triticum vulgare); Fagaceae (*Ficus* sp.)	Bilgrami *et al.*, 1991
Apiospora serenensis (Larrondo & Calvo) Pintos & P. Alvarado	*Arthrinium serenense* Larrondo & Calvo [as '*serenensis*']	-	-	10.1 - 11.2 × 7.8 - 9.5 µm	-	Unknown				JAMMU AND KASHMIR (Gulmarg)	Ranunculaceae (*Aconitum heterophyllum*)	Hafeez *et al.*, 2022
Apiospora sphaerosperma (Pers.) Pintos & P. Alvarado	*Arthrinium phaeospermum* (Corda) M.B. Ellis; *Arthrinium phaeospermum* var. *indicum* K.R. Khan & Sullia	-	5 - 65 × 5 µm	8 - 12 µm diam. in face view, 5 - 7 µm thick	Conidia lenticular, rather dark golden brown with a hyaline band at the junction of the two sides	Unknown				RAJASTHAN (Jodhpur); KARNATAKA (Mangalore); MEGHALAYA (Cherrapunji); ASSAM (Golaghat); ORISSA (Bhubaneshwar); MAHARASHTRA (Melghat Forest, Thane, Mulund, Mumbai)	Capparaceae (*Crateva adansonii*); Convolvulaceae (sweet potato); Poaceae (*Bambusa* sp., *Cymbopogon citratus*); Acoraceae (*Calamus viminalis*); Nyctaginaceae (*Bougainvillea spectabilis*)	Bilgrami *et al.*, 1991; Hande *et al.*, 2014; Manoharachary *et al.*, 2022

Arthrinium caricicola Kunze & J.C. Schmidt	*Arthrinium caricicola* Kunze & J.C. Schmidt	140–400 µm in diameter	15–100 × 3–5 µm	(37–)44–51(–55) µm diam. in frontal view, (8–)9–11(–12) µm diam. in side view	Conidia fusiform or broadly spindle-shaped, smooth-walled, broader at the middle, tapering towards the narrowly rounded ends, dark brown with a hyaline rim	Unknown	MAHARASHTRA (Melghat Forest)	Poaceae (*Bambusa* sp.)	Hande *et al.*, 2014
Arthrinium pucc inioides Kunze	*Arthrinium puccinioides* Kunze	50 - 400 µm in diameter	20 - 140 × 3 - 4 µm	(8-)9 - 11(-12) × 8 - 9 µm	Conidia dark brown, smooth, polygonal with rounded angles to hemispherical, with one or two concentric pale rings	Unknown	MADHYA PRADESH (Sagar)	Soil	Manoharachary *et al.*, 2022
Arthrinium spha erospermum Fuc kel	*Arthrinium sphaerosper mum* Fuckel	up to 500 µm long	10 - 90 × 2 - 3 µm	6 - 9 µm diam	Conidia very densely packed in the conidiophore, globose or subglobose, dark gold to gold-brown in colour, smooth-walled	Unknown	MEGHALAYA (Cheerapunji)	Poaceae	Sarbhoy *et al.*, 1986
Arthrinium spor ophlaeum Ces.	*Arthrinium sporophlaeu m* Ces.	300 - 1200 × 150 - 650 µm	30 - 130 × 2 - 4 µm	(10-)11 - 14(-15) × (5-)6 - 8(-9) µm	Conidia brown, smooth, lemon-shaped in face view, triangular with the outer edge curved and rounded angles in side view	Unknown	UTTARAKHAND (Nainital, Dehradun, Mussoorie); MAHARASHTRA (Palghar)	Cyperaceae (*Eriophoru m comosum*)	Bilgrami *et al.*, 1991; Dubey and Pandey, 2023
Neoarthrinium urticae (M.B. Ellis) Ning Jiang	*Arthrinium urticae* M.B. Ellis	100-250 µm diam. or elongated up to 1 mm.	40-74 × 1.5-2 µm	5-6 (5.6) µm diam	Conidia slightly compressed and oval or elliptical in side view	Unknown	ASSAM (Jorhat)	Insect (*Scirpophag a incertulas*)	Manoharachary *et al.*, 2022

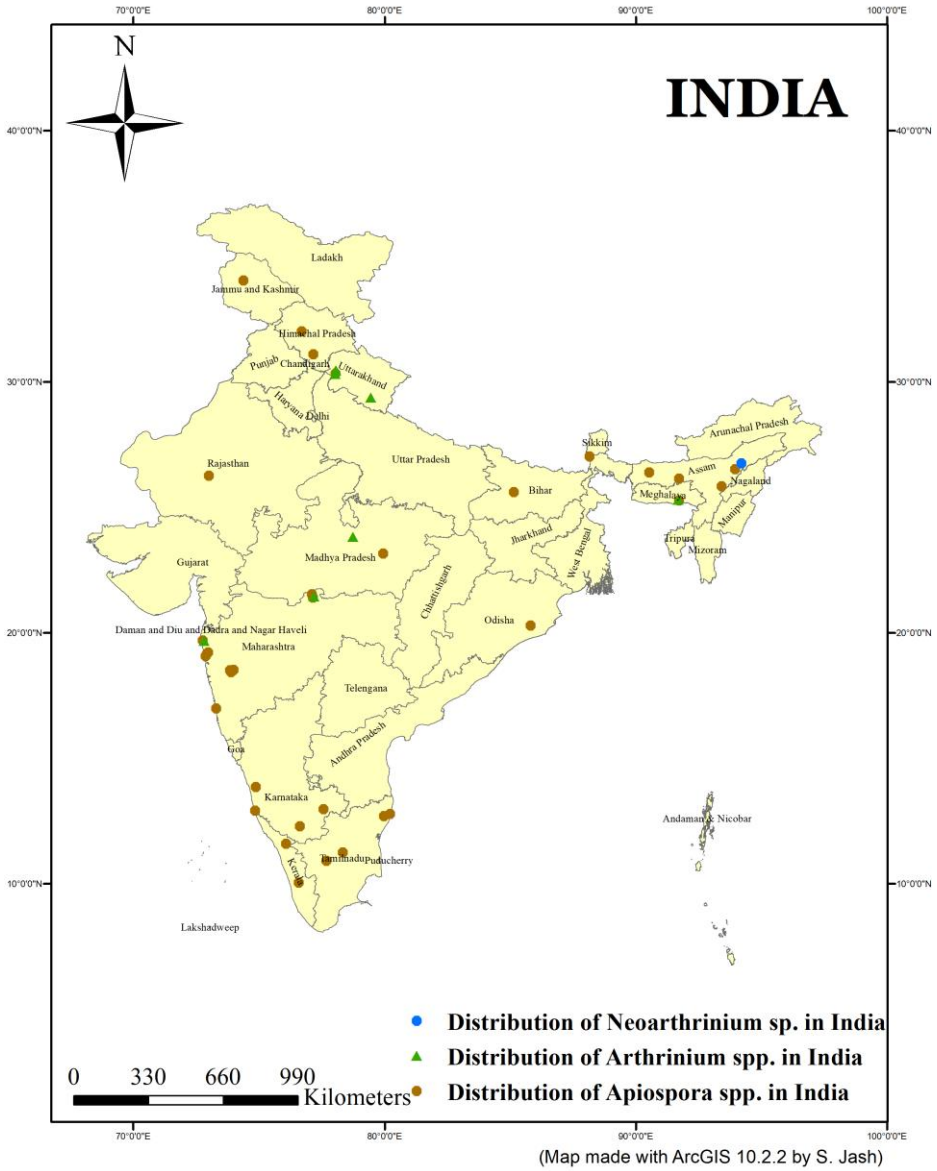

Figure 3: Distribution of the species of *Apiospora*, *Arthrinium* and *Neoarthrinium* in India

DISCUSSION

Most of the reports of *Apiospora* and *Arthrinium* from India are based on only morphological characters, which are very overlapping and not enough to distinguish species, even sometimes genera as well (Bilgrami *et al.*, 1991; Hande *et al.*, 2014; Manoharachary *et al.*, 2022) and thus can be considered as cryptic. Only a few reports have sequence data to confirm the identity of the genus as well as of species (Sharma *et al.*, 2014; Rana *et al.*, 2017; Hafeez *et al.,* 2022; Dubey and Pandey, 2023). As per the recent taxonomic status of these two genera based on polyphasic approach, a total of 14 Indian species of *Arthrinium* are now treated as species of *Apiospora* and one as a species of *Neoarthrinium* (Index Fungorum, 2025) and hence, currently only four Indian species exist under the genus *Arthrinium viz. Arthrinium caricicola* Kunze & J.C. Schmidt, *Arthrinium puccinioides* Kunze, *Arthrinium sphaerospermum* Fuckel and *Arthrinium sporophlaeum* Ces.

As far as host range is concerned, most of the Indian *Apiospora* species parasitize the plants of the family Poaceae (Sarbhoy *et al.*, 1986; Bilgrami *et al.*, 1991; Bhat and Kendrick, 1993; Hande *et al.*, 2014; Manoharachary *et al.*, 2022; Dubey and Pandey, 2023). Although very few species are also reported from Capparaceae, Convolvulaceae, Euphorbiaceae, Fabaceae, Fagaceae, Solanaceae, and dead twigs, soils, dungs, and guts of insects

(Bilgrami *et al.*, 1991; Crous and Groenewald, 2013; Sharma *et al.*, 2014; Crous *et al.*, 2015; Rana *et al.*, 2017; Hafeez *et al.*, 2022; Manoharachary *et al.*, 2022; Dubey and Pandey, 2023). On the other hand, species of *Arthrinium* have no such kind preferences and are equally distributed among many host families including Cyperaceae, Poaceae, etc. (Bilgrami *et al.*, 1991; Hande *et al.*, 2014; Manoharachary *et al.*, 2022; Dubey and Pandey, 2023). Only one species of *Neoarthrinium* has been reported so far from India within the gut of an insect (Manoharachary *et al.*, 2022). Species of *Apiospora* is majorly distributed in Peninsular India, specifically in the Western Ghats and in the Himalayan region along with a few scattered distributions in central India (Fig.3) whereas, species of *Arthrinium* are only reported in the Himalayan region and central to western India (Fig.3).

CONCLUSION

From this study, it is concluded that there is no authentic report of the genus *Arthrinium* in India based on genomic sequence data, hence extensive and inclusive surveys are required for systematically identifying and documenting the diverse species of *Apiospora* and *Arthrinium* in India. However, this study reveals that ITS sequence can distinguish the genera *Apiospora* and *Arthrinium* to some extent but multi-gene phylogeny is the only way to confirm the speciation of these two genera. Besides this, comprehensive surveys across all states of India, along with more detailed research in all aspects, are essential to fill the gap and provide a clearer understanding of the taxonomic status and distribution patterns of Indian species of *Apiospora* and *Arthrinium*.

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