diseases was also made (Table 2). Only Kosi was found resistant in different combinations of diseases (Figure 1 *c*). Two varieties, namely Himalaya and Kalka, showed resistance to rust and leaf spot diseases. Variety Damroo showed moderately resistant reaction to powdery mildew, leaf spot, leaf blight, and stem blackening and rot disease combinations. Two genotypes, S-10-11-45 and S-13-2-125, were found moderately resistant to rust and moderately susceptible to powdery mildew and leaf spot disease. SS-15 genotype showed susceptible reaction against all the diseases.

Based on the present study, variety Kosi of menthol mint was identified as resistant, showing multiple disease resistance. This variety has been granted US Patent (no. PP 12,426) on 26 February 2002. Additionally, this genotype is highly productive covering about 80% of the menthol mint-growing areas and is quantitatively commercially acceptable by the farmers and industry[10]. The result presented here has been also validated by achieving the EOAI-SOM Award 2003–05 for the development and dissemination of legendary variety Kosi of *M. arvensis*. This variety can be utilized for breeding programmes to develop multiple disease-resistant varieties against five major fungal diseases of menthol mint in India.

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Phylogenetic implications of hemipenial morphology in Sri Lankan agamid lizards

While useful in differentiating some of the taxa at the species level[1], the morphology of reptile hemipenes has often been considered to be of limited phylogenetic value[2,3] because of remarkable divergence even within individual genera[4–6]. Here we test for similarity between a molecular phylogeny and a phylogeny based on 15 morphological character states in the hemipenes of 17 of the 18 species (in six genera) of dragon-lizards in Sri Lanka (Squamata: Agamidae) and show that (a) molecular and morphological phylogenies show remarkable congruence, and (b) hemipenial morphology is informative in resolving supra-specific relationships among these lizards.

The Sri Lankan dragon-lizards include three endemic genera, *Lyriocephalus* (one species), *Cophotis* (two species) and *Ceratophora* (five species), and three non-endemic genera *Otocryptis* (two species), *Calotes* (seven species) and *Sitana* (one species). Although recent molecular analyses[7,8] have shown all these genera to belong to the subfamily Draconinae, some forms exhibit highly derived characters such as the rostral horns of *Ceratophora*, ovoviviparity of *Cophotis* and the highly developed extension of the canthus rostralis in *Lyriocephalus*.

Because there is no consensus on what constitutes plesiomorphic and apomorphic states in the reptile hemipenis[3], and on the relative phylogenetic importance of these characters, we gave equal weights to all 15 character states used in the morphological analysis as follows (score '1' for 'yes', and '0' for 'no', using standard hemipenial nomenclature[9]; see Table 1): (1) hemipenis divided for more than half its length; (2) flounces present; (3) apex of each lobe divided symmetrically both laterally and medially by sulcus; (4) sulcus spermaticus bifurcated; (5) a fleshy cardioid structure present at the base of the ventral sulcus; (6) lateral and medial sulcus distinct throughout the length of each lobe; (7) length of entire organ greater than its width; (8) minute denticulation present on calyces; (9) sulcus traverses apex; (10) each lobe with more than 11 flounces; (11) ventral sulcus with transverse ridges; (12) transverse ridges present along more than half of length of the ventral sulcus; (13) calyces subequal along the entire length of the organ; (14) entire length of the lateral and medial sulcus with calyces; (15) calyces present only on the lower half of both lateral and medial sulci.

We used PAUP (version 4.0 b10)[10] to construct a cladogram based on these character states under a maximum parsimony criterion (character state transformation–accelerated) and a heuristic search with stepwise addition starting tree option, random stepwise addition and TBR branch-swapping option. The tree was

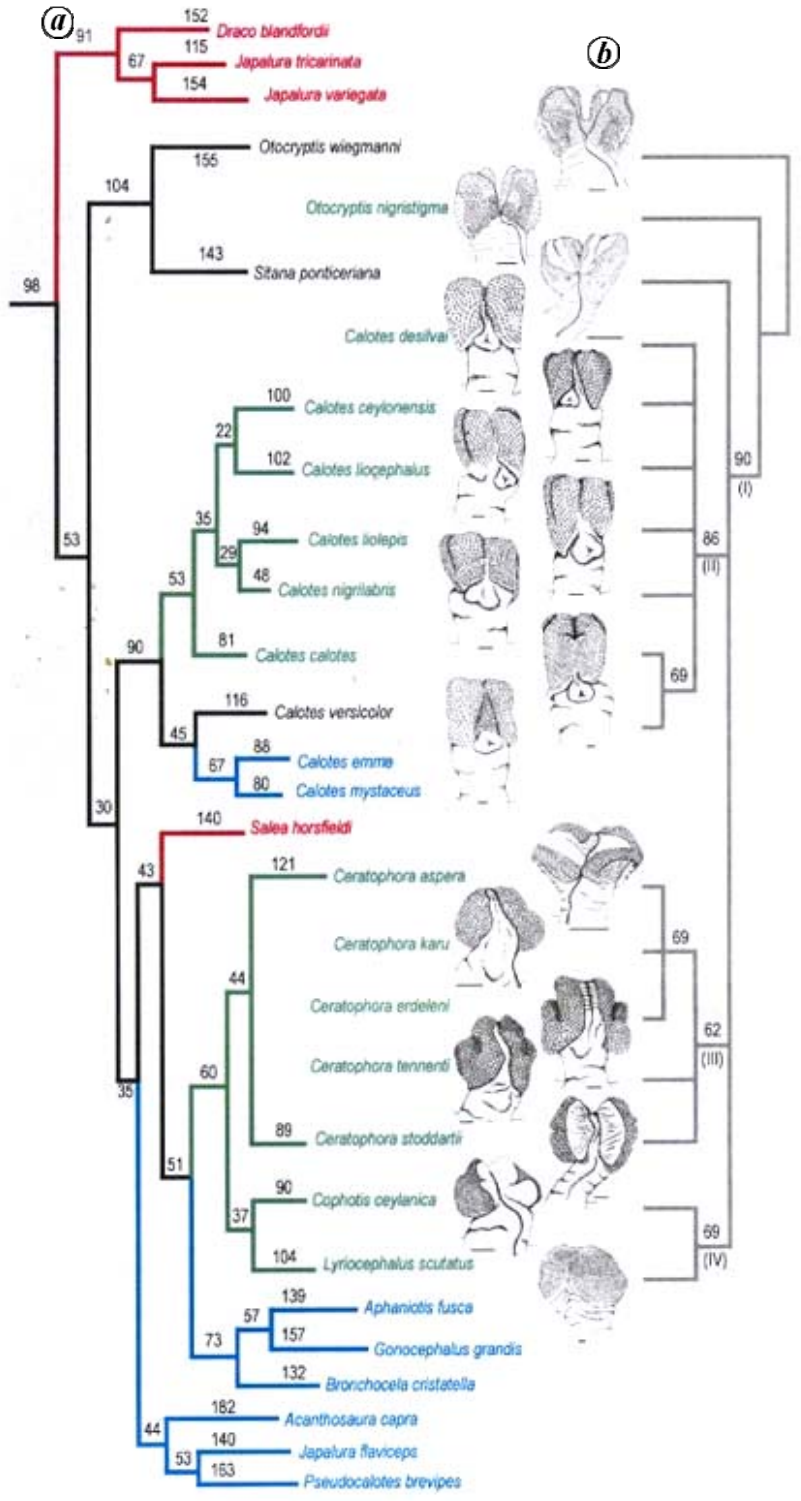

Figure 1. Relationships of Sri Lankan agamid lizards based on phylogenies derived from (***a***) 1041 (informative) bases of aligned mitochondrial DNA positions[7] for 12 species, with relative branch-length indicated above each branch, and (***b***) 15 character states determined by morphology of the hemipenes for 17 species. Drawings of hemipenes are not to scale, depict ventral view, and are centred vertically to the branches of the cladogram on right (***b***). Colour codes for distribution of species are as follows: green, Endemic to Sri Lanka; red, Occurs in India; black, Common to India and Sri Lanka; blue, Southeast Asia. Key generic synapomorphies include: (I) Sulcus spermaticus not bifurcated; (II) A fleshy cardioid structure present at the base of the ventral sulcus, lateral and medial sulci distinct throughout length of each lobe; (III) Sulcus traverses hemipenial apex and (IV) Width of hemipenial organ greater than its length. Scale bar = 1 mm.

left unrooted. We used bootstrap analysis to determine support for the nodes (full heuristic, retaining groups with a frequency greater than 50%, 100 replicates).

A single maximum parsimony tree was recovered (tree length = 15). The tree (Figure 1) clearly shows distinct clades representing the genera recognized by both morphological and molecular phylogenies[7], suggesting that hemipenial characters are indeed useful in diagnosing between genera. For instance, the two species of *Otocryptis* (bootstrap = 90), five species of *Ceratophora* (bootstrap = 62) and seven species of *Calotes* (bootstrap = 90) form monophyletic clades. The endemic genera *Lyriocephalus* and *Cophotis* also, form a tight clade, recovering the same relationships derived in recent molecular analyses[7].

At the species level, however, hemipenial characters were not always diagnostically informative. For example, within the genus *Ceratophora*, *C. stoddartii* and *C. tennentii* are indistinguishable by their hemipenial morphology. Likewise, among the island's seven species of *Calotes*, only three (*C. calotes*, *C. ceylonensis* and *C. versicolor*) have mutually distinctive hemipenes. For example, the hemipenes of *C. calotes* and *C. versicolor* are indistinguishable from each other, but clearly distinguishable from all other insular congeners by having calyces present only on the lower half of both lateral and medial sulci; likewise *C. liolepis*, *C. liocephalus* and *C. desilvai* are also distinguishable by their hemipenial morphology, while *C. ceylonensis* differs from the other six species by having the entire length of lateral and medial sulcus with calyces.

At the supra-species level, however, several genera among the Sri Lankan Agamidae show synapomorphic hemipenial character states. For example, the genera *Otocryptis* and *Sitana* have the hemipenis divided for more than half its length and flounces present on the hemipenial lobe. *Otocryptis* itself has the apex of each hemipenial lobe divided symmetrically both laterally and medially by a sulcus, and the sulcus spermaticus bifurcated. These two character states are absent in its sister genus *Sitana*. The state of having the sulcus traverse the hemipenial apex is shared by all members of the genus *Ceratophora*, while the presence of a fleshy cardioid structure at the base of the ventral sulcus, and having the lateral and medial sulci distinct

Table 1. Character and state matrix of hemipenial–morphological characters used in phylogenetic analysis (score 1 for 'yes' and 0 for 'no')

	Character no.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Otocryptis wiegmanni	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0
Otocryptis nigristigma	1	1	1	1	0	0	1	0	0	1	0	0	0	0	0
Sitana ponicerianа	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Lyriocephalus scutatus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Cophotis ceylanica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratophora stoddartii	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0
Ceratophora tennentii	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Ceratophora karu	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0
Ceratophora aspera	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0
Ceratophora erdlerni	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0
Calotes calotes	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1
Calotes nigrilabris	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Calotes versicolar	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1
Calotes ceylonensis	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0
Calotes liolepis	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Calotes liocephalus	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Calotes desilvai	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0

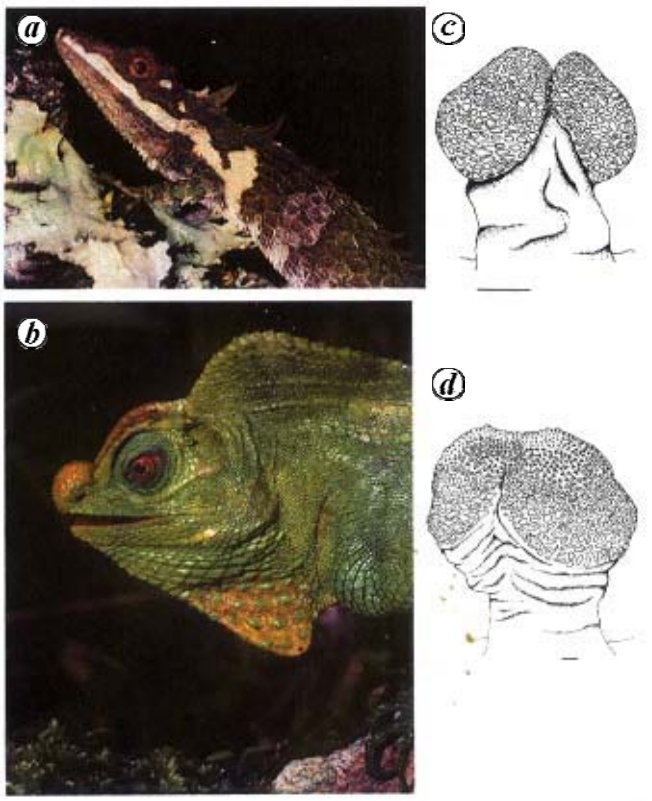

Figure 2. Despite their obvious morphological dissimilarity, the sister genera *Cophotis* (***a***, ***c***) and *Lyriocephalus* (***b***, ***d***), both of which are endemic to Sri Lanka, share a similar hemipenial morphology (shown here in ventral view). Scale bar = 1 mm.

throughout the length of each lobe, is apparently synapomorphic in the genus *Calotes*. Although they are grossly divergent in overall appearance (Figure 2), a sister relationship is demonstrated for *Cophotis* and *Lyriocephalus* based on analyses of both hemipenial morphology and mtDNA. These genera share a unique derived character among the Sri Lankan agamids in that the width of the hemipenial organ is greater than its length. The presence of minute denticulations on the calyces, however, is unique to the monotypic genus *Lyriocephaus*. Interestingly, the present morphological analysis shows also that *Lyriocephalus* + *Cophotis* constitute the sister group of *Ceratophora*[8], from which they diverged ca. 14 Mya.

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