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RESEARCH ARTICLE

Pseudovivipary in the Tuberous *Eriocaulon* (Eriocaulaceae)

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Abstract

Pseudovivipary is a strategy adopted by the plants to survive in extreme environmental condition through asexual reproduction, and enabling seedlings to establish more rapidly. *Eriocaulon tuberiferum* is an endemic, tuberous and Vulnerable species found on the high-altitude lateritic plateaus of Northern Western Ghats, India. This communication documents the first-ever report of tuberous *Eriocaulon* species showcasing both tubers and pseudovivipary simultaneously. The plants had tubers, fully-developed, and mature inflorescence, and mature infructescence containing seeds at different stages of germination. This paper discusses the occurrence of new an example of vivipary from tuberous *Eriocaulon* species and explores the adaptive significance of vivipary in the Eriocaulaceae.

Keywords: Endemic, Eriocaulaceae, Tuberous, Vivipary, Vulnerable.

Introduction

Vivipary is a unique process in which seeds begin to germinate within the fruit, leading to early embryo development while the seeds are still attached to the parent plant. This germination of viviparous seeds typically takes place prior to the complete desiccation of the fruit, while it is still connected to the parent plant, an occurrence that is relatively uncommon among angiosperms (Farnsworth, 2000). Vivipary has been reported in fewer than 195 flowering plant species belonging to 143 genera and 80 families (Cota-Sánchez and Abreu, 2007), representing less than 0.1% of angiosperms. Two main types of vivipary have been described in flowering plants: true vivipary and pseudovivipary, which are equally distributed (50/50) among plant families (Elmqvist and Cox 1996). In true vivipary, plants produce sexual offspring, which are later dispersed as the pericarp wall ruptures due to embryo growth. The best-known cases of true vivipary in angiosperms are documented in the mangroves of the Rhizophoraceae (*Bruguiera* Lam., *Rhizophora* L.) and Avicenniaceae (*Avicennia* L.) (Pannier and Pannier 1975; Rao et al., 1986; Tomildson, 1986). Pseudovivipary is a method of asexual reproduction in which new plantlets are generated instead of the usual sexual reproductive structures (Elmqvist and Cox, 1996). This phenomenon is widespread in monocots, particularly in the Poaceae (Beetle, 1980; Elmqvist and Cox, 1996), where numerous examples have been reported. Comprehensive review of vivipary in plants was given by Elmqvist and Cox (1996) and Farnsworth (2000).

Pseudovivipary is a surviving strategy aimed at facilitating species adaptation, enabling those species to endure and thrive in adverse or stressful conditions (Cota-Sánchez and Abreu, 2007). Thus far, pseudovivipary of Eriocaulaceae has received little attention. The scarce number of case-studies on reproductive biology as well as the dispersal of diaspores and propagules within the family contributes to a narrow understanding of its reproductive versatility and understanding the diverse dispersal strategies in Eriocaulaceae is crucial for ecological, phylogenetic, and conservation considerations (Trovó and Stützel, 2011). Madison (1977) pointed out that vivipary is common in the epiphytic taxa of the Araceae, Cactaceae and Gesneriaceae. Literature surveys have identified vivipary in only 12 species across six genera within the family Eriocaulaceae (Table 1). *Eriocaulon* L. is the largest and most widespread genus of

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Table 1: Previously reported vivipary in Eriocaulaceae.

Genus	*Species*	*Distribution (as per POWO, 2023)*	*Reference*
Comanthera	*C. nivea*	Brazil	Lombello et al. (2019)
Eriocaulon	*E. bamendae*	Cameroon, Nigeria	Phillips (2000)
	E. inapertum	Northern Territory	
	E. lividum	Australia	
	E. modestum	Brazil, Uruguay	
	E. sexangulare	Bangladesh, Borneo, Cambodia, Caroline Is., China Southeast, Hainan, Jawa, Laos, Madagascar, Malaya, Myanmar, Nansei-shoto, New Guinea, Philippines, Sri Lanka, Sumatera, Taiwan, Thailand, Vietnam	Leach (2017)
	E. willdenovianum	Borneo, Cambodia, Caroline Is., Madagascar, Malaya, Mauritius, Myanmar, New Guinea, Northern Territory, Philippines, Sri Lanka, Sulawesi, Sumatera, Thailand, Vietnam	
Leiothrix	*L. spiralis*	Brazil	Coelho et al. (2006)
	L. vivipara	Brazil	
Mesanthemum	*M. alenicola*	Equatorial Guinea	Liang et al. (2019)
Paepalanthus	*P. scirpeus*	Brazil	de Andrade et al. (2011)
Syngonanthus	*S. restingensis*	Brazil	Hensold et al. (2012)

Eriocaulaceae, with about 486 species widely distributed across the tropics and subtropics worldwide (POWO, 2023). Ansari and Balakrishnan (2009) reported 85 species of *Eriocaulon* from India, including five taxa of doubtful occurrence. Since then, many novelties of *Eriocaulon* have been documented from India (Mane et al., 2021). In India, the genus is represented by 105 species, with 70% of them exclusively endemic. These species are mainly distributed in the Western Ghats and Eastern Himalaya hotspot (Darshetkar et al., 2021). Globally, only four tuberiferous *Eriocaulon* species have been identified, *Eriocaulon dalzellii* Körn., *E. idukkianum* Manudev, Robi and Nampy, *E. meenachilense* Anoop and Robi and *E. tuberiferum* A.R.Kulk. and Desai. Remarkably, all these species are reported as endemic to India (Mane et al., 2021).

Eriocaulon tuberiferum was initially described from on the Masai plateau, in the Kolhapur district of Maharashtra, India. This species is exclusively endemic to the higher lateritic plateaus in northern Western Ghats of Maharashtra and Karnataka states (Sanjappa and Sringeswara, 2019; Mane et al., 2021). According to the IUCN (2023), it is assessed in the category "Vulnerable" due to its declining population. *Eriocaulon tuberiferum* predominantly thrives in ponds and puddles situated on the higher altitude lateritic plateaus (800-1200 m) of the Northern Western Ghats (Figure 1). These areas endure extreme climatic conditions year-round. To cope and adapt to this harsh environment, the species do not only set seeds but also produces tubers in its rootstock. These tubers remain dormant during unfavourable conditions and germinate in the following monsoon season, utilizing stored nutrients to generate new plantlets (Mane et al., 2021).

During the floristic study of the lateritic plateaus of Western Ghats, we discovered collected an interesting specimen from Sada plateau, Chorala ghat, Belgavi district, Karnataka, India, belonging to the *Eriocaulon*. Subsequent examination, through a scrutiny of the protologue, type specimen, and relevant literature (Ansari and Balakrishnan 2009), confirmed its identity as *E. tuberiferum*. In this study, we are presenting the first-ever documentation instance of pseudovivipary in a tuberous species of *Eriocaulon* and also first report of pseudovivipary within Indian Eriocaulaceae. The discovery of pseudovivipary in *E. tuberiferum*, expands the overall number of pseudoviviparous species within Eriocaulaceae.

Materials and Methods

Live plant specimens, along with rootstocks were collected during field visits spanning different months from July to September. The specimens of *E. tuberiferum* were specifically collected from Sada plateu (Chorala ghat), Belgavi district of Karnataka state (Figure 1). Careful observations were conducted on viviparous inflorescence and root tubers within their natural habitat and under stereo-microscope. The accurate identification of the studied species was ensured through a comprehensive examination of the protologue and relevant literature (Ansari and Balakrishnan 2009). Voucher specimens of identified species are deposited in the Herbarium of the Department of Botany, Shivaji University, Kolhapur (SUK!, RNM- 310).

Results

Eriocaulon tuberiferum exhibits a pseudovivipary reproductive strategy, thriving in puddles and running water streams. During our observations in the Sada plateau,

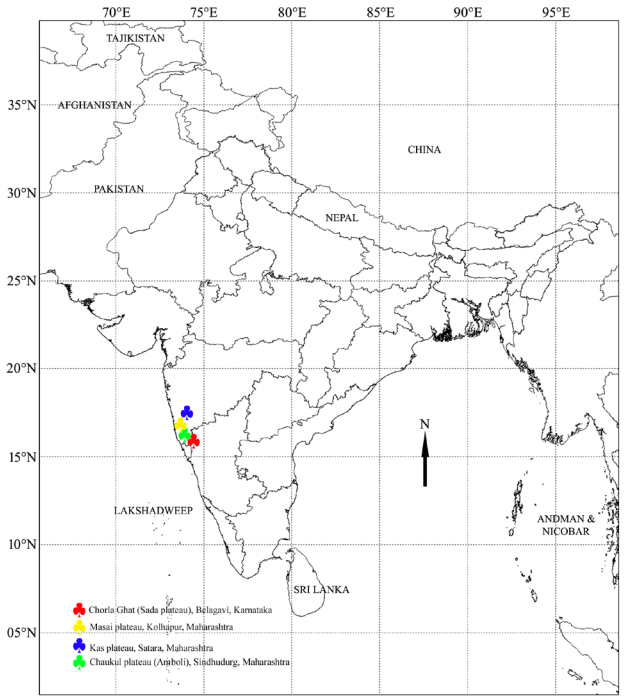

Figure 1: Distribution Map of *Eriocaulon tuberiferum* A.R.Kulk. and Desai

we documented various phases of transition (see Figure 2): A) plant showing pseudovivipary, B) plant in natural habitat, C- L) heads with various stages of germinating offspring, M- R) germinating plantlets from tubers, S) inflorescence of germinated plantlet. Remarkably, prior to dispersal, without undergoing any dormancy period, seeds germinate and produce an outgrowth while still attached to the inflorescence head, showcasing a viviparous type of seed germination. These germinated seeds then develop into mature individuals that remain attached to the mother plant.

Discussion

Pseudovivipary is a relatively uncommon phenomenon in *Eriocaulon* species. In related families like Poaceae, pseudovivipary can arise due to genetic factors, injury, or adverse environmental conditions (Beetle, 1980). Submerged conditions have also been identified as a contributing factor (Milton et al., 2008). Humidity also plays a crucial role, as vivipary is frequently observed during the rainy seasons when humidity levels are relatively high (Arber, 1934; Bhowmik and Datta, 2014). Similar occurrences of vivipary are noted in other plant families, including Asteraceae, Melastomataceae and Zingiberaceae. In these cases, vivipary is as a result of high humidity and continuous rainfall (Karmakar and Hazra, 2016; Bhadra et al., 2013; Veranso-Libalah et al., 2023). Viviparous germination is recognized as the most advanced form of epigeal germination modification. This strategy enhances the

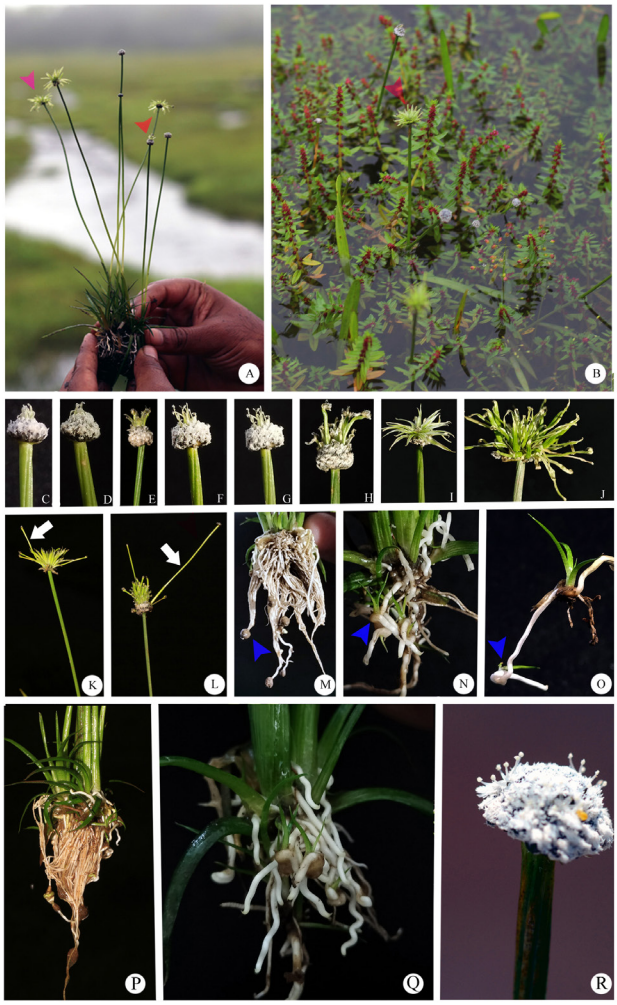

Figure 2: Various stages of pseudovivipary in *Eriocaulon tuberiferum*

likelihood of seedling survival and provides a broader range for seedling dispersal during the early stages of growth (Karmakar et al., 2019).

Eriocaulon species are commonly found in wetland habitats, including ponds, puddles, running water streams, and waterlogged soils. The phenomenon of vivipary observed in *Eriocaulon* may represent an adaptation to these aquatic environments, where fluctuating water levels pose challenges to traditional seed germination. By initiating germination while still attached to the parent plant, *Eriocaulon* ensures that its offspring have a greater chance of survival in these waterlogged conditions. It is conceivable that vivipary may have evolved in *Eriocaulon* as a specific response to ecological challenges presented by these plants over their evolutionary history. Studying the evolutionary context of vivipary within the genus can provide insights into the selective pressures that may have favoured this reproductive strategy, shedding light on the intricate relationship between *Eriocaulon* species and their wetland habitats.

The availability of water in the soil significantly influences plant reproduction and survival (Crawford, 1990). The collection locality of *E. tuberiferum* situated on higher lateritic plateau in Northern Western Ghats, experiences low soil cover, high rainfall and elevated humidity during the monsoon season. *Eriocaulon tuberiferum* exhibiting pseudovivipary were observed during the rainy season, succeeded by a period of dry weather. Capitalizing on favourable conditions and ensuring germination and dispersal of offspring, pseudovivipary is triggered while plantlets remain attached to the mother plants. The induction of pseudovivipary in *E. tuberiferum* may be attributed to the high humidity and precipitation levels. Given the significance of rain for growth and reproduction of *Eriocaulon*, the adoption of vivipary by *E. tuberiferum* could be an adaptive strategy to thrive in these conditions. This adaptation ensures the survival of its offspring in adverse conditions by enabling germination and establishment while remaining attached to the mother plant. The production of tubers is one of the adaptive strategies displayed *E. tuberiferum* to secure the future progeny. Additionally, pseudovivipary aids in survival during the unfavourable conditions and facilitating the establishment of offspring. This mechanism contributes to a greater number of individuals of thriving in the extremely harsh conditions of lateritic plateaus.

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