Natural Compounds, Pharmacological Activities, and Conservation of *Eria* (Orchidaceae)

S. Nurfadilah(✉)

Purwodadi Botanic Garden-Research Center for Plant Conservation, Botanic Gardens, and Forestry, East Jawa, 67163 Purwodadi, Pasuruan, Indonesia
fadilahzr@gmail.com

Abstract. *Eria* is one of the most important medicinal orchid genera. The present study aimed to summarise natural compounds, pharmacological activities, and conservation of *Eria* to reveal the potential of the genus as bioresources for natural product-based medicines and to highlight the importance of conservation of the genus in its development for bioresources for medicines. *Eria* contains 39 natural compounds from different classess of secondary metabolites including alkaloids (2), terpenoids (2), phenolic compounds (1), flavonoids (4), flavanone (2), bibenzyls (3), and phenanthrenes (8), tannins (2), sterols (3) steroids (1), coumarins (1), quinones (2), and others (8). Furthermore, *Eria* possesses various pharmacological activities including antioxidant, antinociceptive, antipyretic, antiinflammatory, and antibacterial activities. A vast array of bioactive compounds and pharmacological activities of *Eria* indicates that the genus has potential as bioresources of natural products to be developed as medicines. *Erianin*, a natural compound initially isolated from *Eria carinata* and further has been found in other orchid species, has been found to possess anticancer properties. In the development of *Eria* as bioresources for natural products for medicinal purposes, orchid conservation approach is required to ensure the long-term survival of the orchids and for the sustainable use of the orchids.

Keywords: Natural compound · Pharmacological activities · Conservation

1 Introduction

Orchidaceae is one of the largest plant family with approximately 25,000 orchid species distributed across the world [1]. The plant family is wellknown as ornamental plants with several genera that possess unique, showy, large, and fragrant flowers, such as *Phalaenopsis, Dendrobium, Paphiopedilum,* and others; and some other genera that have unique patterned-leaves, such as *Goodyera, Macodes,* and others [2, 3]. Furthermore, Orchidaceae is also recognised as medicinal plants with several genera that have been used as herbal medicines to treat a wide range of ailments and diseases including genera of *Coelogyne, Dendrobium, Eria, Habenaria,* and others [4].

M. Fadilah et al. (Eds.): IcoBioSE 2021, ABSR 32, pp. 432–449, 2023.
https://doi.org/10.2991/978-94-6463-166-1_54

Eria is one of the most important medicinal orchid genera. The genus distributed in tropical and subtropical Asia to Pacific [5]. The name of *Eria* refers to the hairiness of the flowers and inflorescences and is often used as a spot-character in identification [6]. *Eria* belongs to the complex tribe Podochileae (Orchidaceae). The genus has long been treated as a large and morphologically diverse genus with approximately 350 species [7]. An updated classification of *Eria* using molecular markers lead to the divergence of *Eria* into 21 genera including *Eria, Pinalia, Mycaranthes, Callostylis*, etc., with *Eria* it self consisted of approximately 50 species [5, 6].

Phytochemical screening, isolation, identification, and characterisation of bioactive compounds of *Eria* has shown that *Eria* contained a wide range of secondary metabolites, i.e. alkaloids, terpenoids, phenolic compounds (flavonoids, stilbenoids, tannins), sterols, coumarins, quinones, and others [8, 9, 10, 11, 12, 13, 14, 15, 16, 17]. Moreover, *Eria* has been well-studied to possess a variety of biological activities including antioxidant, antinociceptive, antipyretic, antiinflammatory, and antibacterial activity [9, 10, 18]. The bioactive compounds and pharmacological effects of *Eria* indicate the potential of *Eria* as bioresources for medicines and can be developed as natural products for pharmacological purposes.

For the development of *Eria* as natural products-based medicines in a large scale for pharmaceutical industries, conservation approach is required for the long-term survival and sustainable use of *Eria. In vitro* propagation of orchids is one of essential conservation programs to provide a large number of seedlings and plants utilised as bioresources for the development of plants as natural medicines and to produce biomass and bioactive compounds [19, 20]. Propagation of *Eria* through *in vitro* seed germination and tissue culture has been reported to be successful to generate a large number of seedlings [21, 22] that can support the development of *Eria* as the bioresources for natural products-based medicines.

The present study aimed to summarise natural compounds, biological activities, and conservation of *Eria* to reveal the potential of *Eria* as bioresources for natural products for pharmacological purposes, and to emphasize the importance of conservation of *Eria* for the long-term survival and the sustainable use of *Eria* (Fig. 1).

Fig. 1. A map of distribution of *Eria* [23]

2 Materials

A comprehensive scientific investigation was performed by analysing data of natural compounds, biological activities, and conservation of *Eria* obtained from various reliable sources including journals, magazines, and other sources using a combination of key words of 'natural compounds + *Eria*', 'biological activities + *Eria*', and 'conservation + *Eria*'. Verification of accepted name of the species was performed using a source from the Plant List (http://www.theplantlist.org/). Chemical classes and chemical structure of the compounds were confirmed from PubChem (https://pubchem.ncbi.nlm.nih.gov/) database. Chemical structure of the compounds was drawn using ChemDraw Ultra 12.0 Software.

3 Results and Discussion

3.1 Natural compounds of Eria

Various bioactive compounds have been isolated and characterised from some species of *Eria* including *Eria pauciflora, E. pseudoclavicaulis, E. tomentosa, E. marginata, E. pauciflora, E. javanica, E. carinata,* and *E. lasiopetala* [9, 10, 11, 12, 13, 14, 15, 16, 17, 24]. A total of 39 bioactive compounds from different class of secondary metabolites have been identified from *Eria* including alkaloids, terpenoids, phenolic compounds (flavonoids, stilbenoids, tannins), sterols, coumarins, quinones, and other compounds.

3.1.1 Alkaloids

Alkaloids have been characterised from *Eria pauciflora* and *E. pseudoclavicaulis* [9, 24]. Alkaloids are known to possess a wide range of pharmacological activities, such as antioxidant, antiinflammatory, antinociceptive, antimicrobial, anticancer, larvicidal, and nematicidal activities [25–28]. A pharmacologically active alkaloid, quinine, has been isolated and identified from *E. tomentosa* [10]. Previous studies have shown that quinine possessed antimalarial and analgesic effects [29] (Table 1).

3.1.2 Terpenoids

Terpenoids have been identified from *Eria pseudoclavicaulis* and *E. tomentosa* (Joseph et al. 2018, Akter et al. 2020). Terpenoids have been shown to possess various biological activities including anticancer, antiinflammatory, and antinociceptive activity [30–32]. A biologically active terpenoids, β-amyrin, has been isolated from *E. marginata* [11]. Previous studies have demonstrated a variety of pharmacological effects of β-amyrin including antiinflammatory, antioxidant, and antibacterial effects [33–35].

Table 1. Natural compounds of *Eria*

Class of secondary metabolites	Subclass	group	Compounds	Species name	Plant parts	References
Alkaloids			Alkaloids (1)	*Eria pauciflora* Wight	Root, leaf, pseudobulb	[8]
				Eria pseudoclavicaulis Blatt	leaf	[9]
			Quinine (2)	*Eria tomentosa* (J.Koenig) Hook.f	leaf, bulb and root extract	[10]
Terpenoids			Terpenoids (3)	*Eria pseudoclavicaulis* Blatt	Root, leaf, pseudobulb	[8]
				Eria tomentosa (J.Koenig) Hook.f	leaf, bulb and root extract	[10]
			β-amyrin (4)	*Eria marginata* Rolfe		[11]
Phenolic compounds	Phenolic compounds		Phenolic compounds (5)	*Eria pseudoclavicaulis* Blatt	Leaf	[9]
				Eria marginata Rolfe		[11]
	Flavonoids		Flavonoids (6)	*Eria pauciflora* Wight	Leaf	[12]
				Eria pauciflora Wight	Root, leaf, pseudobulb	[8]
				Eria pseudoclavicaulis Blatt	leaf	[9]

(*continued*)

Table 1. (*continued*)

Class of secondary metabolites	Subclass	group	Compounds	Species name	Plant parts	References
			Anthocyanins (7)	*Eria pseudoclavicaulis* Blatt	Root, leaf, pseudobulb	[8]
			Flavones 6-Hydroxy (8)	*Eria javanica*	leaf	[13]
			flavonone glycoside (9)	*Eria marginata* Rolfe		[11]
		Flavanone	Pinocembrin (10)	*Eria marginata* Rolfe		[11]
			Naringenin (11)	*Eria marginata* Rolfe		[11]
	Stilbenoids		batatasin III (12)	*Eria marginata* Rolfe		[11]
		Bibenzyls	Erianin (13)	*Eria carinata* Gibson	Whole plant	[14]
			3,4'-dihydroxy-5-methoxy bibenzyl (14)	*Eria marginata* Rolfe		[11]
		Phenanthrenes	Nudol (15)	*Eria carinata* Gibson	Whole plant	[15]
			Flavanthrin (16)	*Eria lasiopetala* (Willd.) Ormerod	Whole plant	[16]
			Coelonin (17)	*Eria lasiopetala* (Willd.) Ormerod	Whole plant	[16]
			Flavanthridin (18)	*Eria lasiopetala* (Willd.) Ormerod	Whole plant	[17]
			Flavanthrinin (19)	*Eria lasiopetala* (Willd.) Ormerod	Whole plant	[17]

(*continued*)

Table 1. (*continued*)

Class of secondary metabolites	Subclass	group	Compounds	Species name	Plant parts	References
			3,7-dihydroxy-2,4-dimethoxyphenanthrene (20)	*Eria lasiopetala* (Willd.) Ormerod	Whole plant	[17]
			Erianthridin (21)	*Eria marginata* Rolfe		[11]
			4-methoxy-9,10-dihydrophenanthrene-1,2,7-triol (22)	*Eria marginata* Rolfe		[11]
	Tannins		Tannins (23)	*Eria pauciflora* Wight	Leaf	[12]
				Eria pauciflora Wight	Root, leaf, pseudobulb	[8]
				Eria pseudoclavicaulis Blatt	Leaf	[9]
				Eria tomentosa (J.Koenig) Hook.f	leaf, bulb and root extract	[10]
			Phlobatannins (24)	*Eria pseudoclavicaulis* Blatt	Root, leaf, pseudobulb	[8]
				Eria pseudoclavicaulis Blatt	leaf	[9]
				Eria tomentosa (J.Koenig) Hook.f	leaf, bulb and root extract	[10]

(*continued*)

Table 1. (*continued*)

Class of secondary metabolites	Subclass	group	Compounds	Species name	Plant parts	References
Sterols			β-sitosterol (25)	*Eria marginata* Rolfe		[11]
			β-sitosteryl-3-O-β-D-glucopyranoside-2'-O-palmitate (26)	*Eria marginata* Rolfe		[11]
			Phytosterol (27)	*Eria pseudoclavicaulis* Blatt	leaf	[9]
Steroids			Steroids (28)	*Eria pseudoclavicaulis* Blatt	Root, leaf, pseudobulb	[8]
				Eria pseudoclavicaulis Blatt	leaf	[9]
				Eria tomentosa (J.Koenig) Hook.f	leaf, bulb and root extract	[10]
Quinones			Quinones (29)	*Eria pauciflora* Wight, *Eria pseudoclavicaulis* Blatt	Root, leaf, pseudobulb	[8]
			Anthraquinones (30)	*Eria tomentosa* (J.Koenig) Hook.f	leaf, bulb and root extract	[10]
Coumarins			Coumarins (31)	*Eria pseudoclavicaulis* Blatt	Root, leaf, pseudobulb	[8]
				Eria tomentosa (J.Koenig) Hook.f	leaf, bulb and root extract	[10]

(*continued*)

Table 1. (*continued*)

Class of secondary metabolites	Subclass	group	Compounds	Species name	Plant parts	References
Benzaldehydes			Vanillin (32)	*Eria marginata* Rolfe		[11]
Alcohol			Mannitol (33)	*Eria marginata* Rolfe		[11]
Fats and oils			fats (34) and oils (35)	*Eria pseudoclavicaulis* Blatt	leaf	[9]
Carbohydrates			Saponins (36)	*Eria pauciflora* Wight	Root, leaf, pseudobulb	[8]
				Eria pseudoclavicaulis Blatt	leaf	[9]
				Eria tomentosa (J.Koenig) Hook.f	leaf, bulb and root extract	[10]
			Carbohydrates (37)	*Eria pseudoclavicaulis* Blatt	leaf	[9]
			Glycosides (38)	*Eria pseudoclavicaulis* Blatt	leaf	[9]
				Eria tomentosa (J.Koenig) Hook.f	leaf, bulb and root extract	[10]
				Eria pauciflora Wight, *Eria pseudoclavicaulis* Blatt	Root, leaf, pseudobulb	[8]
			cyanogenic glycosides (39)	*Eria pauciflora* Wight	leaf	[12]

3.1.3 Phenolic Compounds

Total phenolic compounds have been identified from *Eria pseudoclavicaulis* and *E. marginata* [9, 11]. Phenolic compounds are classified as simple phenols and polyphenols based on the number of phenol units in the molecules [36–38] Flavonoids, stilbenoids, and tannins are secondary metabolites classified in phenolic compounds.

Flavonoids

Total flavonoids have been characterised from *Eria pauciflora* and *E. pseudoclavicaulis* [8, 9, 12]. Anthocyanin, a flavonoid, has been isolated from *E. pseudoclavicaulis* [8]. Other biologically active flavonoids, pinocembrin and naringenin, have been isolated from *E. marginata* [11]. Pinocembrin has been shown to exhibit antimicrobial, antioxidant, antiinflammatory, and anticancer effects [39]. Furthermore, naringenin has been reported to possess antioxidant, antitumor, antiviral, antibacterial, antiinflammatory, antiadipogenic, and cardioprotective effects [40].

Stilbenoids

Stilbenoids consist of some groups of secondary metabolites including bibenzyls, phenanthrenes, and others. Batatasin III, a stilbenoid, has been identified from *E. carinata* and *E. marginata* [11, 14]. Previous studies have demonstrated that batatasin III possessed cytotoxic activity against lung cancer cell lines by inhibiting the cancer migration and invasion [41], antiinflammatory properties [42, 43], and antidiabetic agents [44].

Some bibenzyls including erianin and 3,4'-dihydroxy-5-methoxy bibenzyl have been identified from *E. carinata* and *E. marginata* (Majumder and Joardar 1984, Sun et al. 2014). Erianin was a natural compound initially identified from *Eria carinata*, and further this bioactive compound has been found in other orchid species, such as *Dendrobium chrysotoxum* [14, 45–47]. Erianin has been widely reported to possess cytotoxic activity against various cancer cells, such as human colorectal cancer, leukemia, hepatoma Bel7402 and melanoma A375 [45, 48, 49].

Phenanthrenes have been identified from *Eria* including erianthridin, nudol, flavanthrin, coelonin, flavanthridin, flavanthrinin, 3,7-dihydroxy-2,4-dimethoxyphenanthrene, and 4-methoxy-9,10-dihydrophenanthrene-1,2,7-triol. Previous studies have demonstrated that erianthridin possessed anticancer activity [50]. Nudol has been reported to possess antioxidant activity [51] and exhibited antiproliferative activity against osteosarcoma cells [52]. Moreover, a previous study has reported coelonin as a bioactive compound exhibiting an antiinflammatory acivity [53].

Tannins

Tannins have been isolated from *E. pauciflora*, *E. pseudoclavicaulis*, and *E. tomentosa* [8–10, 12]. Moreover, phlobatannins have been identified from *E. pseudoclavicaulis* and *E.tomentosa* [8–10].

Sterols

Sterols (phytosterols) have been identified from *Eria marginata* and *E. pseudoclavicaulis* [9, 11]. A biologically active β-sitosterol has been isolated from *E. marginata* [11]. Sitosterol is recognised to possess a wide range of biological activities including antibacterial, anticancer, antidiabetic, and antiinflammatory activities [54–57].

Quinones

Quinones have been isolated from *E. pauciflora* and *E. pseudoclavicaulis* [8]. A previous study has shown quinone exhibited anticancer activities [58]. Anthraquinones have been characterised from *E. tomentosa* [10]. A vast array of biological activities of anthraquinones have been demonstrated in previous studies, including anticancer, antipathogenic microorganisms, antiinflammatory, antioxidant, antiosteoporosis, antidepression, and anticonstipation [59].

Coumarins

Coumarins have been isolated from *E. pseudoclavicaulis* and *E. tomentosa* [8, 10]. These natural compounds have been reported to possess a wide range of biological activities including antiinflammatory, anticoagulant, antibacterial, antifungal, antiviral, anticancer, antihypertensive, antitubercular, anticonvulsant, antiadipogenic, antihyperglycemic, antioxidant, and neuroprotective properties [60].

3.1.4 Miscellaneous Compounds

Other various compounds have been characterised from *Eria* including vanillin (benzaldehyde), carbohydrates, mannitol (alcohol), fats, and oils.

Vanillin has been isolated and characterised from *Eria marginata* [11]. Previous studies have reported a wide range of biological activities of vanillin including anticancer, antioxidant, antiinflammatory, neuroprotective, antisickling (sickle cell anaemia), antiamyloid aggregation and inhibition of nonenzymatic glycation, antifungal, antibacterial, antibiotic potentiation, antiquorum sensing, nephroprotective, cardioprotective, hepatoprotective, pancreatoprotective, wound healing, antiviral, cytoprotective, increase bioavailability of drugs, DNA binding, antitremor, and cosmetical [61].

Carbohydrates have been characterised from *Eria pseudoclavicaulis* (Sahaya et al. 2012). Saponins have been identified from *E. pauciflora, E. pseudoclavicaulis*, and *E. tomentosa* [8–10]. Glycosides have been isolated from *E.pseudoclavicaulis*, *E. tomentosa*, and *E. pauciflora* [8–10].

Other compounds such as mannitol has been identified from *Eria marginata* [11]. Moreover, fats and oils also have been isolated and characterised from *Eria pseudoclavicaulis* [9].

Natural Compounds of *Eria*

3.2 Biological Activities of Eria

Eria has been reported to possess a wide range of biological activities including antioxidant, antinociceptive, antipyretic, antiinflammatory, and antibacterial activities [9, 10, 18].

3.2.1 Antioxidant Activity

Eria javanica and *E. pseudoclavicaulis* have been shown to possess antioxidant activity [9, 10]. [10] assessed the antioxidant activity of the methanolic, n-hexane, butanol-1 and DCM extracts of the root, leaf and stem of *E. tomentosa* and the standard antioxidant ascorbic acid on the basis of the free radical scavenging effect on the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH, MWt.394). The results of the study showed that the scavenging activity ranged from 64.13% to 94.876% and butanol-1 fraction was the most effective in scavenging activity towards DPPH indicating its efficacy in antioxidant activity [10].

Moreover, [9] investigated the antioxidant activity of five extracts of *Eria pseudoclavicaulis* and the standard ascorbic acid based on the scavenging activity of the extracts towards free radicals 2, 2-diphenyl-1-picrylhydrazyl (DPPH). The results of the study showed that water extract of *Eria pseudoclavicaulis* leaves exhibited the best scavenging activity towards DPPH with IC50 = 318.0 μg.

3.2.2 Antinociceptive Activity

[18] investigated the antinociceptive activity of *Eria javanica* through acetic acid-induced writhing methods. The frequency of response of abdominal writhing such as contraction of the abdominal muscle and stretching of the hind limbs in mice that have been treated by various extracts of *Eria javanica* (methanolic extracts 200 mg/kg and 400 mg/kg, ethanolic extracts 200 mg/kg and 400 mg/kg, chloroform extracts 200 mg/kg and 400 mg/kg, n-hexane extracts 200 mg/kg and 400 mg/kg), and 50 mg/kg Diclofenac sodium and subsequently treated by intra peritoneal injection of acetic acid was observed. These treatments were compared to control treatment using treatments of saline 0,1 ml/10 g bw. Furthermore, the percentage of inhibition of writhing is calculated using a formula, % inhibition of writhing = wc-wt/wc x 100% (wc = number of writhing responses in the control group; wt = number of writhing responses in the treated groups (Bhuiya *et al.* 2017). Results of the study showed that various extracts of *E. javanica* exhibited analgesic activity with percentage of inhibiton of writhing ranged from 27.86%-70% [18].

3.2.3 Antipyretic Activity

Antipyretic activity of *Eria* has been demonstrated in *E. javanica* [18]. [18] evaluated the antipyretic activity of a variety of extracts of *E. javanica* (methanolic extracts 200 mg/kg and 400 mg/kg, ethanolic extracts 200 mg/kg and 400 mg/kg, chloroform extracts 200 mg/kg and 400 mg/kg, n-hexane extracts 200 mg/kg and 400 mg/kg) in albino Wistar rats by inducing pyrexia with a suspension of Brewer's yeast 15% in distilled water. The rectal temperatures of the rats were taken before and after the injection of the suspension of Brewer's yeast, and after the treatment with a variety of extracts

of *E. javanica* (1 h, 2 h, 3 h, and 4 h). The results of the study showed the significant antipyretic activity [18].

3.2.4 Antiinflammatory Activity

Eria javanica has been shown to possess antiinflammatory activity [18]. [18] investigated the antiinflammatory effect of various extracts of *E. javanica* (methanolic, ethanolic n-hexane, and chloroform extracts, each at 400 mg/kg), and compared to the control (0.1% Tween 80 in normal saline with DMSO (at a dose of 0.1 mL/10 g body weight) and the standard (Diclofenac sodium at 100 mg/kg body weight) in albino Wistar rats using the Carrageenan-induced rat's paw edema test. In the study, the control, the standard, and various extracts of *E. javanica* samples were administered orally, and one hour later 0,1 ml of 1% of Carrageenan solution was injected to the subplanar surface of the right hind paw of each rat of each group to produce edema. The paw volume was measured before and after 1,2,3, and 4 h after administration of Carrageenan. Percentage of inhibition of edema was calculated based on the formula:

% inhibition of paw volume: $\frac{Vc-Vt}{Vc} \times 100\%$
Vc = Volume of paw at control.
Vt = Volume of paw at tested samples.

The results of the study showed the percentage of paw edema inhibition after 1 h (2.52% - 9.01%), 2 h (4.33%-9.60%), 3 h (9.82%-12.80%), and 4 h (14.69%-24.14%) accross various extracts of *E. javanica.* Inhibition of paw edema by treatment with various extracts of *E. javanica* reflected the antiinflammatory activity of various extracts of *E. javanica* [18].

[10] investigated antiinflammatory activity of various extracts of *E. tomentosa* using heat-induced albumin denaturation assay. The results of the study showed that percentage of inhibitory activity of of various extracts (n- hexane, DCM, methanol, and butanol-1 fraction) of leaves, bulbs, and roots *E. tomentosa* ranged from 72.45% to 97.26%.

3.2.5 Antibacterial Activity

Antibacterial activity of *Eria* has been evaluated in *E. pseudoclavicaulis* [9]. [9] tested various extracts of *E. pseudoclavicaulis* (extracts of petroleum ether, chloroform, ethyl acetate, ethanol, and water) against various bacteria including *Pseudomonas aeruginosa, Enterococcus faecalis, Escherichia coli, Staphylococcus aureus, Bacillus subtilis, Salmonella enterica,* and *Corynebacterium* sp using disc diffusion methods. Zone of inhibition of bacteria growth was measured. The results of the study showed that the zone of inhibiton ranged from 5 mm – 13 mm [9].

Conservation of Eria

Eria has been widely reported to possess essential bioactive compounds and biological activities, thus, the genus is potential to be developed as bioresources for natural products based-medicines. Further research is required for the development of *Eria* as bioresources for natural products based-medicines including its efficacy and toxicity.

For the development of *Eria* as bioresources for natural products based-medicines, conservation approach is required. For the development of *Eria* as natural products-based medicines in a large scale for pharmaceutical industries, conservation approach is required for the long-term survival and sustainable use of *Eria* [61]. This includes:

3.2.6 Propagation of Eria

I*n vitro* Propagation of orchids is a powerful tool in orchid conservation to generate a large number of orchid seedlings that can be used as massive sources in the development of orchids as biosources for natural products based-medicines and to produce biomass and bioactive compounds [19, 20]. Propagation of *Eria* through *in vitro* seed germination and tissue culture has been reported to be successful to generate a large number of seedlings [21, 22]. This can support the development of *Eria* as the bioresources for natural products-based medicines. Further research is required to increase yields of bioactive compounds and secondary metabolites of *Eria.*

3.2.7 Isolation and Preservation of Mycorrhizal Fungi Associated with Eria

Orchids highly depend on the mycorrhizal fungi for their survival. They form symbiotic association with mycorrhizal fungi facilitating nutrient supply for the orchids in the early orchid growth and development. The use of mycorrhizal fungi in the propagation of orchids through symbiotic propagation of orchids has been reported to increase production of secondary metabolites in orchids [63]. Further studies on the symbiotic propagation of *Eria* and analysis of the improvement of yields of secondary metabolites from symbiotic seedlings are required.

4 Conclusions

Eria contains 39 natural compounds from different classess of secondary metabolites including alkaloids (2), terpenoids (2), phenolic compounds (1), flavonoids (4), flavanone (2), bibenzyls (3), and phenanthrenes (8), tannins (2), sterols (3) steroids (1), coumarins (1), quinones (2), and others (8). Furthermore, *Eria* possesses various pharmacological activities including antioxidant, antinociceptive, antipyretic, antiinflammatory, and antibacterial activities. A vast array of bioactive compounds and pharmacological activities of *Eria* indicates that the genus has potential as bioresources of natural products to be developed as medicines. *Erianin*, a natural compound initially isolated from *Eria carinata* and further has been found in other orchid species, has been found to possess anticancer properties. In the development of *Eria* as bioresources for natural products for medicinal purposes, orchid conservation approach is required to ensure the long-term survival of the orchids and for the sustainable use of the orchids (Table 2).

Table 2. Biological activities of *Eria*

Pharmacological activity	Orchid species	Pharmacological Testing	Results	References
Antioxidant activity	*Eria tomentosa* (J.Koenig) Hook.f	DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) scavenging activity assay	Scavenging activity ranged from 64.13%-94.87%	[10]
	Eria pseudoclavicaulis Blatt	1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity assay	scavenging activity with IC50 = 318 µg/ml	[9]
Antinociceptive activity	*Eria javanica* (Sw.) Blume	Acetic acid-induced writhing method	Antinociceptive activity ranged from 50.36%-67.86%	[18]
Antipyretic activity	*Eria javanica* (Sw.) Blume	Yeast-induced pyrexia test in rats	Significant antipyretic activity of ethanolic extracts after 1 h and onwards	[18]
Antiinflammatory activity	*Eria javanica* (Sw.) Blume	Carrageenan-induced rat's paw edema test	the percentage of paw edema inhibition after 1 h (2.52% - 9.01%), 2 h (4.33%-9.60%), 3 h (9.82%-12.80%), and 4 h (14.69%-24.14%) accross various extracts of *E. javanica*	[18]
	Eria tomentosa (J.Koenig) Hook.f	Heat-induced albumin denaturation assay	Antiinflammatory activity ranged from 72.45% to 97.26%	[10]
Antibacterial activity	*Eria pseudoclavicaulis* Blatt	Disc diffusion methods	ZOI againts *Pseudomonas aeruginosa, Enterococcus faecalis, Escherichia coli, Staphylococcus aureus, Bacillus subtilis, Salmonella enterica, Corynebacteria* spp were 5–13 mm	[9]

References

1. R.L. Dressler 1993 Phylogeny and classification of the orchid family Dioscorides Press, Oregon.
2. J Arditti 1991Fundamentals of orchid biology John Wiley and Sons New York
3. LC De, Pathak P, Rao AN, Rajeevan PK 2014 Commercial orchids. De Gruyter tOpen.
4. Teoh. 2016. Medicinal Orchids of Asia
5. *WCSP (2022). 'World Checklist of Selected Plant Families.* Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://wcsp.science.kew.org/ Retrieved 12 August 2022.'
6. Ng YP, Schuiteman A, Pedersen HÆ, Petersen G, Watthana S, Seberg O, Pridgeon AM, Cribb PJ, Chase MW. 2018. Phylogenetics and systematics of *Eria* and related genera (Orchidaceae: Podochileae). Botanical Journal of the Linnean Society 186: 179–201
7. DJ. Mabberley 1987. The plant-book. Cambridge: Cambridge University Press.
8. M. Joseph, Jose L, Sequira S. 2018. A comparative phytochemical screening of four Epidendroid Orchids of Kerala, India. J. Orchid Soc. India, 32: 41-43
9. SB. Sahaya, Sarmad M, Servin WP, Chitra DB. 2012. Preliminary phytochemical screening, antibacterial and antioxidant activity of *Eria pseudoclavicaulis* Blatt. –An endemic orchid of Western Ghats. Am. J. PharmTech Res. 2012; 2(6)518–525
10. MT. Akter, Huda MK, Hoque MM, Rahman M. 2020. Phytochemical Analysis, Antioxidant and Anti-inflammatory Activity of *Eria tomentosa* (Koen.) Hook. f.. In: Khasim S, Hegde S, González-Arnao M, Thammasiri K. (eds) Orchid Biology: Recent Trends & Challenges . Springer, Singapore.https://doi.org/10.1007/978-981-32-9456-1_21

11. Sun, Liu Y, Jiang J, Huang G, Liu B, Liu Y, Zhan R, Chen Y. 2014. Isolation of a New Flavonone Glycoside from *Eria marginata.* Bull. Korean Chem. Soc. 35 (8):2544–2546. https://doi.org/10.5012/bkcs.2014.35.8.2544
12. M. Maridass, Hussain MIZ, Raju G. 2008. Phytochemical Survey of Orchids in the Tirunelveli Hills of South India. Ethnobotanical Leaflets 12: 705-712.
13. Williams 1979
14. P.L. Majumder, Joardar M. 1984. Structure of erianin a new bibenzyl derivative from the orchid *Eria carinata.* Indian Journal of Chemistry Section B Organic Chemistry Including Medicinal Chemistry 23 (11): 1040-1042
15. S.R. Bhandari, A.H. Kapadi, P.L. Majumder, M. Joardar, J.N. Shoolery 1985. Nudol, a phenanthrene of the orchids *Eulophia nuda*, *Eria carinata* and *Eria stricta.* Phytochemistry 24, 801–804
16. P.L. Majumder , S. Banerjee 1988. Structure of flavanthrin, the first dimeric 9,10 dihydrophenanthrene derivative from the orchid. Tetrahedron 44 (23): 7303-7308
17. P.L. Majumder, S. Banerjee 1990. Two stilbenoids from the orchid *Eria flava.* Phytochemistry 29, 3052–3055.
18. NMMA Bhuiya, M. Hasan, Z. Al Mahumud, N. Qais, MSH. Kabir, F. Ahmed, MMN. Uddin. 2017. *In vivo* analgesic, antipyretic, and antiinflammatory potential of leaf extracts and fractions of *Eria javanica.* Journal of Complementary and Integrative Medicine
19. S-L. Chen, H. Yu, H-M. Luo, Q. Wu, C-F. Li, A. Steinmetz 2016. Conservation and sustainable use of medicinal plants: problems, progress, and prospects. Chin Med 11:37
20. S.Y. Park, T.T. Ho, K.Y. Paek 2020. Medicinal Orchids: Production of Bioactive Compounds and Biomass. Khasim et al (Eds.) Springer Nature Singapore Pte Ltd.
21. M.A. Kashem, T.K. Bhowmik, M.M. Rahman. 2020. In vitro propagation of *Eria tomentosa* (Koen.) Hook. f.: An important indigenous medicinal orchid of Bangladesh. Journal of Medicinal Plants Studies 8(4): 206–211
22. B.S. Shibu, P.S. Wesley, S. Moin, Devi BC. 2014. *In vitro* regeneration of *Coelogyne nervosa* A. Rich. And *Eria pseudoclavicaulis* Blatt., threatened orchids of Western Ghats, India. Indian Journal of Experimental Biology 52: 658–663
23. GBIF Secretariat 2021. *Eria* Lindl. GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-10-20.
24. XC. Liu, D. Lai, QZ Liu, L. Zhou, Q. Liu, ZL. Liu 2016. Bioactivities of a New Pyrrolidine Alkaloid from the Root Barks of *Orixa japonica.* Molecules 21, 1665
25. LRA. Menezes, CODS. Costa, ACBdC. Rodrigues, FRdE. Santo, A. Nepel, LM. Dutra, FMA. Silva, MBP. Soares, A. Barison, E.V. Costa, D.P. Bezerra. 2016. Cytotoxic Alkaloids from the Stem of *Xylopia laevigata*, Molecules 21, 890
26. X. Wang, M. Tanaka, S. Krstin, H.S. Peixoto, M. Wink 2016a. The Interference of Selected Cytotoxic Alkaloids with the Cytoskeleton: An Insight into Their Modes of Action. Molecules 2016, 21, 906
27. X. Wang, M. Tanaka, S. Krstin, H.S. Peixoto, M. Wink 2016b. C19-Norditerpenoid Alkaloids from *Aconitum szechenyianum* and Their Effects on LPS-Activated NO Production. Molecules 21, 906
28. J. Achan, A.O. Talisuna, A. Erhart, A. Yeka, J.K. Tibenderana, F.N. Baliraine, Rosenthal PJ,D'Alessandro U. 2011. Quinine, an old anti-malarial drug in a modern world: role in the treatment of malaria. Malaria Journal 10:144
29. G. Kuttan, P. Pratheeshkumar, K.A. Manu, R. Kuttan 2011. Inhibition of tumor progression by naturally occurring terpenoids. Pharmaceutical Biology 49(10): 995–1007
30. V. Prakash 2017. Terpenoids as source of anti-inflammatory compounds. Asian Journal of Pharmaceutical and Clinical Research 10(3):68-76
31. A.G. Guimarães, J.S.S. Quintans, L.J.Q. Júnior. 2013. Monoterpenes with Analgesic Activity—A Systematic Review. Phytotherapy Research.27:1–15

32. N.N. Okoye, D.L. Ajaghaku, H.N. Okeke, E.E. Ilodigwe, C.S. Nworu, F.B.C. Okoye 2014. Beta-Amyrin and alpha-amyrin acetate isolated from the stem bark of *Alstonia boonei* display profound anti-inflammatory activity, Pharmaceutical Biology, 52:11, 1478-1486, https://doi.org/10.3109/13880209.2014.89807
33. B.K. Cardoso, HLM de Oliveira, U.Z. Melo, C.M.M. Fernandez, CFdAA. Campo, Gonçalves JE, Laverde Jr A, Romagnolo MB, Linde GA, Gazim ZC. 2020. Antioxidant activity of α and β-amyrin isolated from *Myrcianthes pungens* leaves, Natural Product Research, 34:12, 1777-1781, DOI: https://doi.org/10.1080/14786419.2018.1525715
34. N. Abdel-Raouf, N.M. Al-Enazi, A.A. Al-Homaidan, I.B.M. Ibraheem, M.R. Al-Othman, A.A. Hatamleh 2015. Antibacterial b-amyrin isolated from *Laurencia microcladia*. eohArabian Journal of Chemistry 8:32–37
35. A. Khoddami , M.A. Wilkes, T.H. Roberts 2013. Techniques for Analysis of Plant Phenolic Compounds. Molecules 18: 2328-2375; doi:https://doi.org/10.3390/molecules18022328
36. O. Sytar, A. Borankulova, I. Hemmerich, C. Rauh, I. Smetanska 2014. Effect of chlorocholine chlorid on phenolic acids accumulation and polyphenols formation of buckwheat plants. Biological Research 47:19
37. G.R.V. Rodr´ıguez, H.P. Carlos, A.W. Medrano, J.F. AyalaZavala, C.Y.O. Chen, M.R. Sanchez, H.A. Garc´ıa, E.A. Parrillab, G.A.G. Aguilar 2014. Phenolic compounds: their journey after intake Food Funct. 5, 189
38. A. Rasul, F.M. Millimouno, W.A. Eltayb, M. Ali, Li J, Li X. 2013. Pinocembrin: A Novel Natural Compound with Versatile Pharmacological and Biological Activities. BioMed Research International, Article ID 379850, 9 pages
39. B. Salehi, P.V.T. Fokou, M. Sharifi-Rad, P.Z.R. Pezzani, N. Martins, J. Sharifi-Rad. 2019. The Therapeutic Potential of Naringenin: A Review of Clinical Trials Pharmaceuticals 12, 11; doi:https://doi.org/10.3390/ph12010011
40. T. Pinkhien, N. Petpiroon, B. Sritularak, P. Chanvorachote 2017. Batatasin III Inhibits Migration of Human Lung Cancer Cells by Suppressing Epithelial to Mesenchymal Transition and FAK-AKT Signals. Anticancer Research 37: 6281-6289
41. C. Zhang, D. Ning, J. Pan, C. Chen, C. Gao, Z. Ding, F. Jiang, M. Li 2021. Anti-inflammatory effect fraction of *Bletilla striata* and its protective effect on lps-induced acute lung injury. Mediators of Inflammation, Article ID 6684120
42. F. Jiang, M. Li, H. Wang, B. Ding, C. Zhang, Z. Ding, X. Yu, Lv. Guiyuan 2019. Coelonin, an Anti-Inflammation Active Component of *Bletilla striata* and Its Potential Mechanism. Int. J. Mol. Sci. 20: 4422
43. WP. Hu, Cao GD, Zhu JH, Li JZ, Liu XH. 2015. Naturally occurring Batatasins and their derivatives as α-glucosidase inhibitors. RSC Adv. 5: 82153-82158
44. Y-Q. Gong, Fan Y, Wu D-Z, Yang H, Hu Z-B, Wang Z-T. 2004. In vivo and in vitro evaluation of erianin, a novel anti-angiogenic agent. Eur J Cancer 40(10):1554-1565
45. Y. Zhang, Zhang Q, Xin W, Liu N, Zhang H. 2019. Nudol, a phenanthrene derivative from *Dendrobium nobile*, induces cell cycle arrest and apoptosis and inhibits migration in osteosarcoma cells. Drug Design, Development and Therapy 13: 2591–2601
46. Y. Xiang, Chen X, Wang W, Zhai L, Sun X, Feng J, Duan T, Zhang M, Pan T, Yan L, Jin T, Gao Q, Wen C, Ma W, Liu W, Wang D,WuQ, Xie T, Sui X. 2021. Natural Product Erianin Inhibits Bladder Cancer Cell Growth by Inducing Ferroptosis via NRF2 Inactivation. Front. Pharmacol. 12:775506. doi: https://doi.org/10.3389/fphar.2021.775506
47. S. Yihan, Guofeng L, Qi Z, Danyue S, Jingwei Lv, Jianhua Z. 2020. Dual Targeting of Cell Growth and Phagocytosis by Erianin for Human Colorectal Cancer. Drug Design, Development and Therapy 14: 3301–3313
48. Li YM, Wang HY, Liu GQ. 2001. Erianin induces apoptosis in human leukemia HL-60 cells. Acta Pharmacologica Sinica 22 (11):1018-1022

49. Li Y, Jiang JG. 2018. Health functions and structure-activity relationships of natural anthraquinones from plants. Food and Function 12
50. S. Pothongsrisit, Arunrungvichian K, Hayakawa Y, Sritularak B, Mangmool S, Pongrakhananon V. 2021. Erianthridin suppresses non-small-cell lung cancer cell metastasis through inhibition of Akt/mTOR/p70 S6K signaling pathway. Scientific Reports 11:6618. https://doi.org/10.1038/s41598-021-85675-8
51. N.S. Aminah, Hidayah R, Tanjung M. 2017. Confusarin and nudol, two phenathrene group compounds, from *Dioscorea esculenta* L. and their antioxidant acitivities. Journal of Chemical Technology and Metallurgy 52(6): 1135–1139
52. Y. Zhang, Zhang Q, Wei F, Liu N. 2019. Progressive study of effects of erianin on anticancer activity. OncoTargets and Therapy 12: 5457–5465
53. J. Fusheng, Meiya L, Hongye W, Bin D, Chunchun Z, Zhishan D, Xiaobo Y, Guiyuan Lv. 2019. Coelonin, an Anti-Inflammation Active Component of *Bletilla striata* and Its Potential Mechanism. Int. J. Mol. Sci. 20, 4422; doi:https://doi.org/10.3390/ijms20184422
54. T. Rajavel, R. Mohankumar, G. Archunan, K. Ruckmani, K.P. Devi 2017. Beta sitosterol and Daucosterol (phytosterols identified in *Grewia tiliaefolia*) perturbs cell cycle and induces apoptotic cell death in A549 cells. Scientific Reports 7: 3418
55. M.A. Zeb, S.U. Khan, T.U. Rahman, M. Sajid, S. Seloni 2017. Isolation and biological activity of β-sitosterol and stigmasterol from the roots of *Indigofera heterantha.* Pharmacy & Pharmacology International Journal 5 (5): 204-207
56. Y. Sun, L. Gao, W. Hou, J. Wu. 2020. β-Sitosterol Alleviates Inflammatory Response via Inhibiting the Activation of ERK/p38 and NF-κB Pathways in LPS-Exposed BV2 Cells. BioMed Research International, Article ID 7532306
57. Lu J-J, Bao J-L, Wu G-S, Xu W-S, Huang M-Q, Chen X-P, Wang Y-T. 2013. Quinones Derived from Plant Secondary Metabolites as Anti-cancer Agents. Anti-Cancer Agents in Medicinal Chemistry13: 456-463
58. K.N. Venugopala, V. Rashmi, B. Odhav 2013. Review on Natural Coumarin Lead Compounds for Their Pharmacological Activity. BioMed Research International, Article ID 963248, 14 pages
59. S.S. Arya, J.E. Rookes, D.M. Cahill, S.K. Lenka. 2021. Vanillin: a review on the therapeutic prospects of a popular favouring molecule. Advances in Traditional Medicine 21:415–431
60. S. Nurfadilah 2020. Utilization of orchids of Wallacea region and implication for conservation. IOP Conf. Ser.: Earth Environ. Sci. 473 012063
61. R, Hampejsová, M. Berka, V. Berková, J. Jersáková, J. Domkářová, F. von Rundstedt, A. Frary, I. Saiz-Fernández, B. Brzobohatý and M. Černý (2022) Interaction With Fungi Promotes the Accumulation of Specific Defense Molecules in Orchid Tubers and May Increase the Value of Tubers for Biotechnological and Medicinal Applications: The Case Study of Interaction Between *Dactylorhiza* sp. and *Tulasnella calospora.* Frontiers in Plant Science 13:757852. doi: https://doi.org/10.3389/fpls.2022.757852