

Full Length Research Paper

Morphological characterization and elemental analysis of *Euryops floribundus* N.E. Br in relation to its secretory structures

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Received 17 July, 2025; Accepted 3 October, 2025

In this study, the morphological characters of the stem, leaves and flowers of *Euryops floribundus* N.E. Br. have been investigated using scanning electron microscope (SEM) and elemental analysis performed using energy dispersive X-ray spectroscopy (EDX). The stem and leaf cross-sections demonstrated phloem-associated secretory ducts in vascular bundles. Besides the secretory ducts inside the stem, this plant species is assumed to develop another secreting strategy to deal with mechanical injury. The shape and occurrence of such structures might be used as valid indicative trait of the plant studied. The leaves exhibited amphistomatic nature with epicuticular wax deposition predominantly located around the stomatal chambers of the leaves. *E. floribundus* disk floret exposed the apical bifid style with stigmatic papillae covering the style branches. Arrangement of sweeping hairs on apical region of the style formed a truncate brush which is assumed to play a significant role in secondary pollen presentation. Elemental analysis determined in the stem and leaves revealed nine elements such as Silicon, Carbon, Calcium, Oxygen, Iron, Magnesium, Potassium, Aluminium and Copper. Most of these elements play necessary functions in the formation of active chemical constituents present in medicinal plants. Some of the structural features obtained could be guidelines for future investigations.

Key words: Energy dispersive X-ray spectroscopy (EDX), scanning electron microscope (SEM), amphistomatic, secretory ducts, stigmatic papilla, sweeping hairs.

INTRODUCTION

The family Asteraceae is the second largest flowering plant family with a wide distribution from subpolar to tropical regions in a wide variety of habitats (Attard and Cuschier, 2009; Funk et al., 2009; Salamah et al., 2019; Umber et al., 2021). Asteraceae species thrive in nearly every habitat (Rolnik and Olas, 2021; Umber et al., 2021). Because of diversity of habitats, this family presents

various anatomical structures, and, in some cases, ecological specialization may occur (Metcalf and Chalk, 1979). Most plants belonging to this family are characterized by bearing their flowers in dense flower heads called capitula. Their flowers are surrounded by an involucre of bracts and each capitulum may appear to be a single flower.

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Figure 1. *E. floribundus* in its natural habitat.
Source: <https://www.inaturalist.org/photos/103756205>.

Some anatomical characteristics have been observed within the Asteraceae family to possess taxonomic importance. These include the presence of various types of secretory and laticiferous canals, occurrence of medullar and cortical vascular bundles, types of glandular and non-glandular trichomes and presence of anomalous secondary thickening (Fahn, 1979; Metcalfe and Chalk, 1979). In many genera of Asteraceae, the presence of secretory structures has been of great taxonomic interest; and their allocation has an important identification value. The several types of secretory structures observed in this family include ducts, cavities, trichomes, idioblasts, floral and extrafloral nectaries (Stefi et al., 2021; Martinez-Quezada et al., 2023). Secretory structures may be classified by their location in the plant, whether external or internal, as well as their exudates. Examples of these are internal oil glands, resin ducts, nectaries, glandular trichomes and others (da Silva et al., 2014; Martinez-Quezada et al., 2023). Secretory structures in plants play a vital role in promoting growth and survival, facilitating environmental interaction, supporting defense mechanisms and for attraction of pollinators and dispersers as well as regulating water loss through transpiration (Li et al., 2024). They can be found in all types of plant organs such as flowers, bark, wood, rhizomes, dried fruits and seeds (Batista and De Souza, 2017; Zeragui et al., 2019). Many species belonging to Asteraceae are applied in therapy because of their high content of pharmacologically active compounds produced by the secretory tissues (Zeragui et al., 2019; Cilia-Lopez et al., 2021). These bioactive compounds play an important role in plant defense functions against pathogens, insects and herbivores (Pagni et al., 2003; Buyisile, 2009). Some members of Asteraceae are

economically important as weeds, are invasive species in particular regions and are toxic to grazing animals (Beentjie, 2010).

Euryops floribundus, a species belonging to the Asteraceae family, is a multi-stemmed perennial shrub which occurs extensively in the Eastern Cape Province of South Africa. Its leaves are narrowly linear with yellow rays and disc florets as is the case for all daisy family members (Figure 1). In general, the style of the pistil in flowers of Asteraceae is long and at the apex gives off two style branches. The pollen presentation of the Asteraceae species is the sweeping hairs that cover the stigma, or it is simply the style branches in basal taxonomic lineages that lack these hairs (Erbar and Leins, 2000; Hong et al., 2008). Erbar and Leins (2015) reported that the sweeping hairs participate in the pollen presentation. *E. floribundus* has spread as a weed in some areas, where it demonstrates invasion of many types of vegetation, especially damaged grassveld. Invasion of this plant is perceived to have reduced the grazing available for domestic livestock (Masibonge et al., 2020). *E. floribundus* is reported to pose a threat to grassland diversity and productivity in the Eastern Cape Province, South Africa. Research by Gxasheka et al. (2025) on phytochemical analysis of the leaves of this plant species revealed the presence of flavonoids, phenolics and tannins in higher levels. They further reported that this plant has allelopathic potential on the germination and seedling growth of *Lactuca sativa* with an overall inhibitory effect. It has a resinous bark and is known locally as “Harpuisbos`1” (Resin bush) (Van der Merwe, 1941).

Although much work has been reported on phytochemical analysis and allelopathic effects of *E. floribundus* regarding its invasive character, there is not

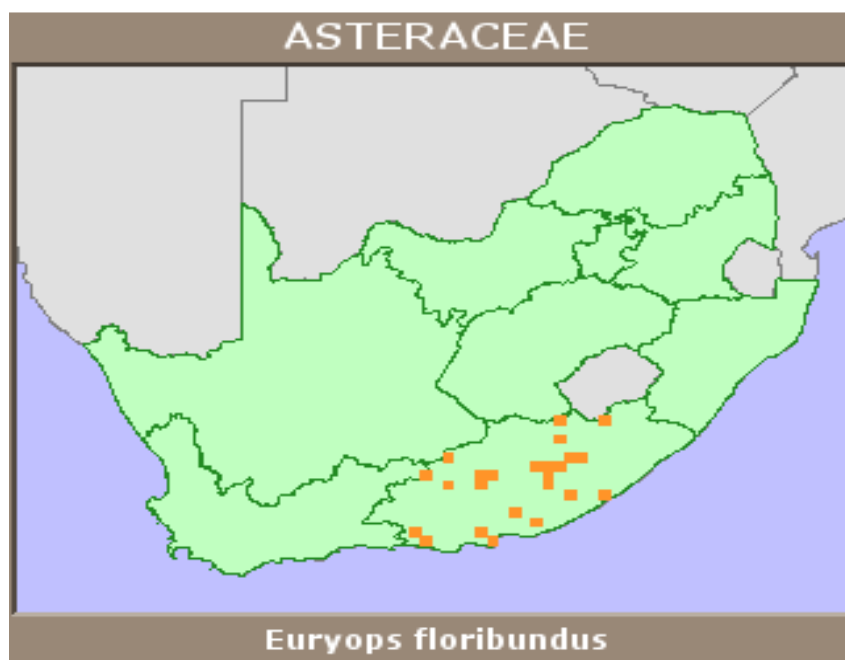


Figure 2. Map showing distribution of *E. floribundus* in South Africa.
Source: Threatened species programme | SANBI red list of South African plants.

much information regarding the morphology of its various organs, the secreting structures and their distribution in the plant. Therefore, the main objective of this paper is to describe the morphology of aerial parts of *E. floribundus* and their secretory structures.

MATERIALS AND METHODS

Plant collection

The plant material was collected from its natural habitat in Nico Malan Pass, Eastern Cape Province, South Africa with permission from community leaders under the Kingdom of Chief Maqoma. It is located between 32.4087° South and 26.8361° east along the road, a few kilometers away from Seymour village. The plant was identified and validated by Professor Cupido of the Botany Department, University of Fort Hare. Voucher specimen (MHI/001/2024) was prepared and deposited at the Giffen Herbarium of the University. The study complied with the University Ethics Committee guidelines and legislation (Ethics Clearance Certificate attached under Institutional Review Board statement: BUW031SMHI01). The distribution map of *E. floribundus* is shown in Figure 2.

Micromorphological characterization

Micromorphological characterization of *E. floribundus* was done with a ZEISS EVO LS15 Scanning Electron Microscope (ZEISS, Oberkochen, Germany). Sections of stems, leaves (0.5 mm × 0.5 mm thick) and flowers were fixed in 3% Glutaraldehyde buffered in 0.05 M sodium cacodylate buffer (pH 7.5) at room temperature for one hour. They were kept in the refrigerator at 4°C until further use. The sections were washed twice with 0.05M sodium cacodylate at pH 7.3 for 5 minutes. This was followed by dehydration with an ethanol series at various concentrations from 10 to 100%. They were critical

point dried with liquid CO₂ using a Quorum K850 (Quorum Technologies, UK) critical point drier machine.

The samples were mounted on the stubs with carbon double-sided tape and sputter coated with gold using a Quorum Q150R ES sputter coater (Quorum Technologies, UK). They were viewed using a Zeiss EVO LS 15 SEM at 5 kV in high vacuum mode. Micrographs were taken to obtain detailed surface information of the specimen.

Anatomical investigation

Sections of stems and leaves (0.5 mm x 0.5 mm thick) were fixed in formaldehyde/acetic acid. They were dehydrated through an alcohol series using a graded series of ethyl alcohol, tertiary butyl alcohol (TBA) and the substitution of TBA with liquid paraffin. The material was infiltrated with paraffin wax in an oven at 70°C. Specimens were embedded in wax, and the top and bottom faces were trimmed to form a ribbon during sectioning. Tissues were cut into thin sections (13 µm²) using a Leitz rotary microtome. Some of the sections were stained with 0.05% toluidine blue and examined with a Zeiss Photomicroscope III.

Elemental composition

The Energy Dispersive X-ray (EDX) analysis was done to determine and evaluate the elemental composition of the substances secreted by this plant. This was performed using a Zeiss Ultra Plus Field Emission Gun Scanning Electron Microscope – FEGSEM (Zeiss, Oberkochen, Germany) at 20 kV using AzTec Software. In order to evaluate the effect of seed mineral composition on imbibition and EC, seed mineral proportion of different atomic number elements was evaluated under a Zeiss EVO SEM using the EDX spectrometry technique. Three seeds of each landrace selection were cryofractured and split into two halves. Seeds were mounted onto stubs and secured using two-way insulating tape and viewed under the Zeiss EVO SEM in variable pressure mode. Seed coat mineral

composition was determined separately for the seed coat and cotyledon structures using INCA software (ETAS Group, Stuttgart, Germany), which is linked to the SEM. In order to evaluate the effect of seed mineral composition on imbibition and EC, seed mineral proportion of different atomic number elements was evaluated under a Zeiss EVO SEM using the EDX spectrometry technique. Three seeds of each landrace selection were cryofractured and split into two halves. Seeds were mounted onto stubs and secured using two-way insulating tape and viewed under the Zeiss EVO SEM in variable pressure mode. Seed coat mineral composition was determined separately for the seed coat and cotyledon structures using INCA software (ETAS Group, Stuttgart, Germany), which is linked to the SEM.

RESULTS

Morphological characterization

SEM results showed that the epidermis in the leaves of *E. floribundus* is characterized by equally distributed stomata on both sides of the leaf surface (Figure 3a and b). The presence of a few nonglandular trichomes was observed on the epidermal layer of the leaves. (Figure 3b and c) It is noteworthy that the leaves revealed wax deposits that appeared to be strategically positioned within the stomatal chambers (Figure 3c and d). These epicuticular wax deposits demonstrated a crystalline structure. These are the characteristic features of plants that grow in arid habitats. The waxes are assumed to originate from the intracellular compartments and were transported to the epidermis. Wax projections on the leaf surfaces continue throughout the period of leaf expansion (Figure 3e and f). The leaves are characterized by having deeply sunken stomata at the base of hypostomatal cavities (Figure 3e and f).

The SEM micrographs of *E. floribundus* stem demonstrated more or less round shape which was characterized by one layer of epidermal cells (Figure 4). The vascular system organization of this plant demonstrated collateral bundles forming a ring between the pith and the cortex (Figure 4a and b). They were separated from one another by sclerenchyma tissue. An interesting feature observed was the presence of accessory bundles which were scattered in the stem cortex (Figure 4a and b). The secretory ducts formed a network across the cortex and were associated with phloem tissue of the vascular bundles (Figure 4a, b and e). An immature developing vascular bundle (Figure 4b) is shown with no secretory duct. The secretory duct is assumed to develop when the vascular bundle has almost completed its development. The cortex consisted of collenchyma cells with thick cell walls (Figure 4c). Most of the collenchyma cells were assumed to be filled with resin. These features are understood to be significant to plants adapted to semi-arid habitats. The secretory ducts appeared to be a common characteristic of the stem for this plant species, with lumen surrounded by a layer of specialized cells (Figure 4d). The interesting feature of the secretory ducts within the plant body was their tight

connection to the phloem. The epithelial cells in the duct exhibited irregular walls with loose appearance (Figure 4d).

One of the diagnostic microscopic characters of *E. floribundus* stem included the presence of specialized cells in the epidermis. Their distribution is assumed to create an efficient defensive system against mechanical injury. They were occasionally found on the exterior surfaces of the stem as epidermal appendages in response to external stimuli (Figure 4e). The formation of these traumatic secretory ducts appeared to be strategically positioned in a deliberately injured region of the stem to exudate internal secretion for wound healing (Figure 4f).

Micrographs of *E. floribundus* capitulum showed that the floret is characterized by calyx which has developed as a bristle pappus (Figure 5a). The five petals were fused at the base with the stigma and style elongated extending beyond the corolla (Figure 5b). This resulted in bifurcation of stigmatic arms which began to reflex exposing extensive papilloid surfaces (Figure 5c). The entire surface of the style is covered by pollen collecting papillae (Figure 5c and d).

The stigmatic papillae of the disc floret cover the inside of the style branch; whilst the sweeping hairs cover the external side (Figure 5c and e). Morphological investigation of the stigma lobes demonstrated stigmatic papillae which are restricted to two ventro-marginal bands along each style branch (Figure 5c and d). The stigmatic region located between the two bands of stigmatic papillae is composed of smooth rectangular-shaped cells that lack pollen grains (Figure 5d).

The disc floret of this plant possessed sweeping hairs which are concentrated on the upper part of the style branches forming the developed appendages (Figure 5e and f). These sterile structures are expanded above the stigmatic area forming a truncate brush at the end of the style branches.

Figure 6a shows pollen grains which were confined to the tip of the style branch with emerging pollen tubes. Some pollen grains are relocated onto other structures of the flower (Figure 6b). SEM micrographs demonstrated pollen located on the corolla lobes with emerging pollen tubes (Figure 6c). The *E. floribundus* capitulum demonstrated tricolpate pollen grains with echinate ornamentation adhering to the corolla lobes (Figure 6d).

Anatomy of *E. floribundus*

Distribution and structure of secretory ducts in the stem of *E. floribundus* demonstrated the initials enclosing the ducts formed differentiated into uniseriate epithelium, lining the intercellular space called a lumen (Figure 7a). These ducts were embedded in the phloem cells throughout their distribution within the stem analyzed and were surrounded by sclerenchyma cells (Figure 7b). The duct epithelium cells show morphological changes

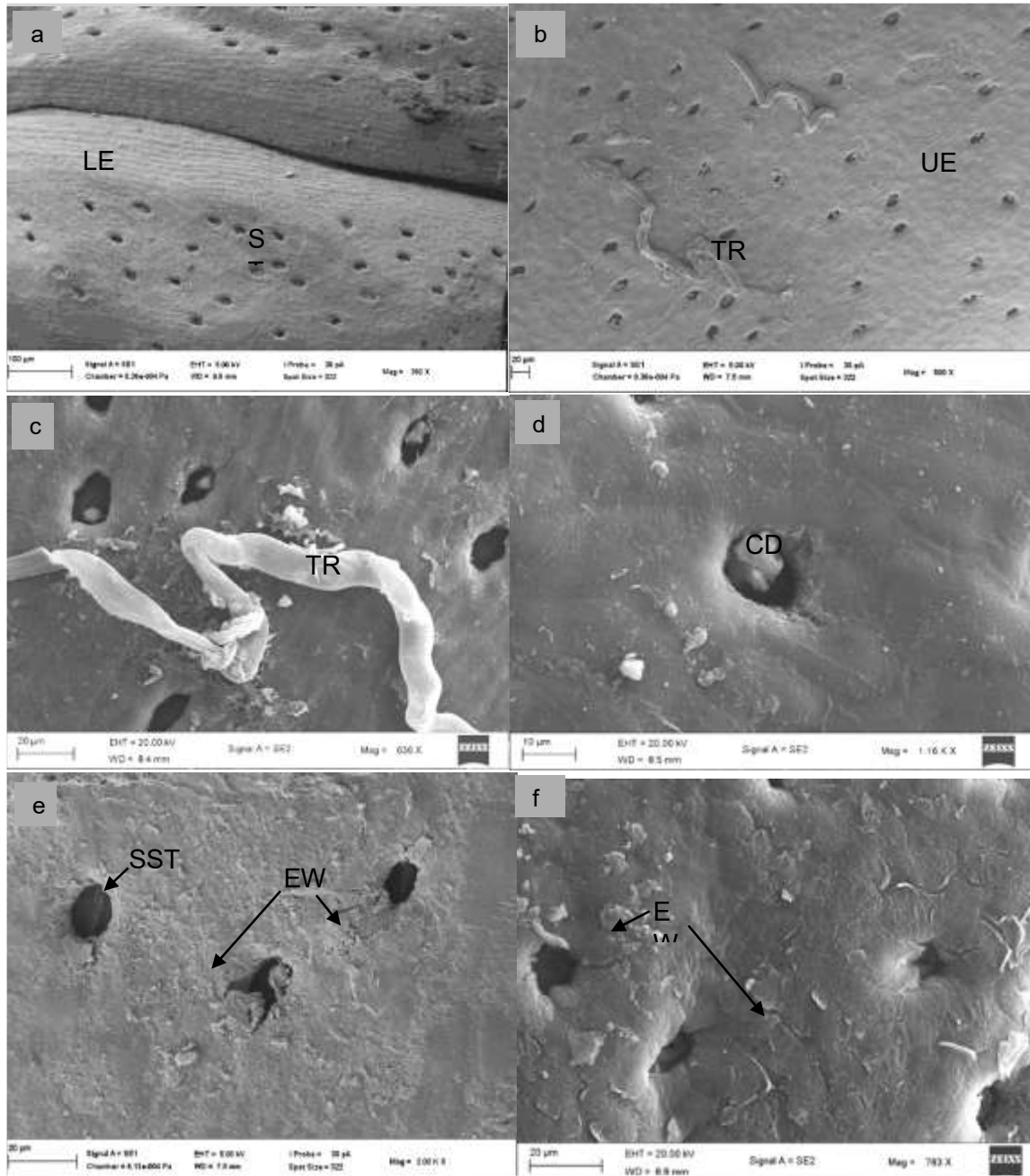


Figure 3. SEM micrographs of *E. floribundus* leaves. (a, b) Sunken stomata on lower and upper epidermal layer. (c). The non glandular trichome on the epidermal layer. (d, e, f) Epicuticular wax in the stomata. Wax deposition on epidermal layer. Sunken stomata which are closed. EW- Epicuticular wax, SST- sunken stomata, TR- trichome, CD- crystalline deposition, LE- lower epidermis, UE- upper epidermis, ST- stomata.

throughout the development stages (Figure 7a and c). In the early stages when the differentiation of duct begins, most cells of the epithelium are isodiametric due to expansion of the periclinal wall facing the lumen (Figure 7b). Late in the development, they present a more flattened shape with straight periclinal walls (Figure 7c). This may be due to transference of secretion to lumen. Figure 7b demonstrated the fusion of adjacent ducts by

lateral coalescence giving rise to wider ducts. The leaves of the plant tested were covered by a thick cuticle and the lower epidermis was characterized by thick periclinal walls (Figure 7d). It is noteworthy to report that the duct complex, including sheath and epithelial cells, was located rather on the lower part of the mesophyll parenchyma cells (Figure 7d and e). Some leaf ducts demonstrated association with photosynthetic cells, and they were not seen on the leaf

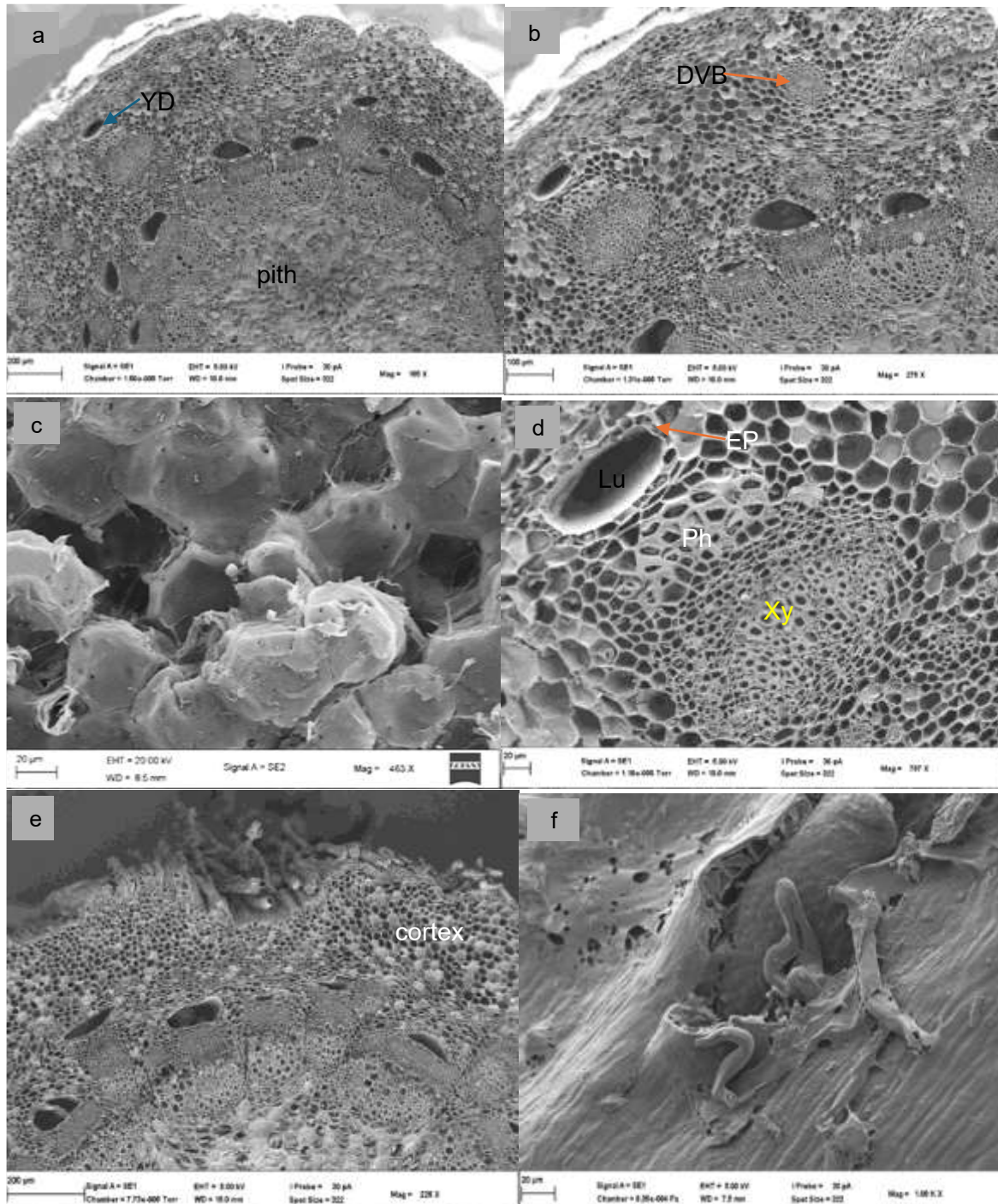


Figure 4. Micrographs of *E. floribundus* stem. (a, b) Transverse section of a stem showing distribution of secretory ducts in the phloem. 4b shows developing vascular bundle, (c) collenchyma cells filled with resin. (d) Epithelial cells in the duct exhibited irregular walls with loose appearance. (e) Induced secretory ducts where the leaf was cut. (f) Traumatic ducts positioned in an injured stem. YD- Young duct, Ph- phloem, Xy – xylem, DVB- developing vascular bundle, EP- epithelial cells, Lu – lumen.

upper surface (Figure 7e). Figure 7f shows the occurrence of closed guard cells in an irregularly shaped lower epidermis. The guard cells modulate the opening and closing of the stomata.

Elemental composition

Based on the elemental composition determined using EDX, the overall crystal-like deposition present inside the

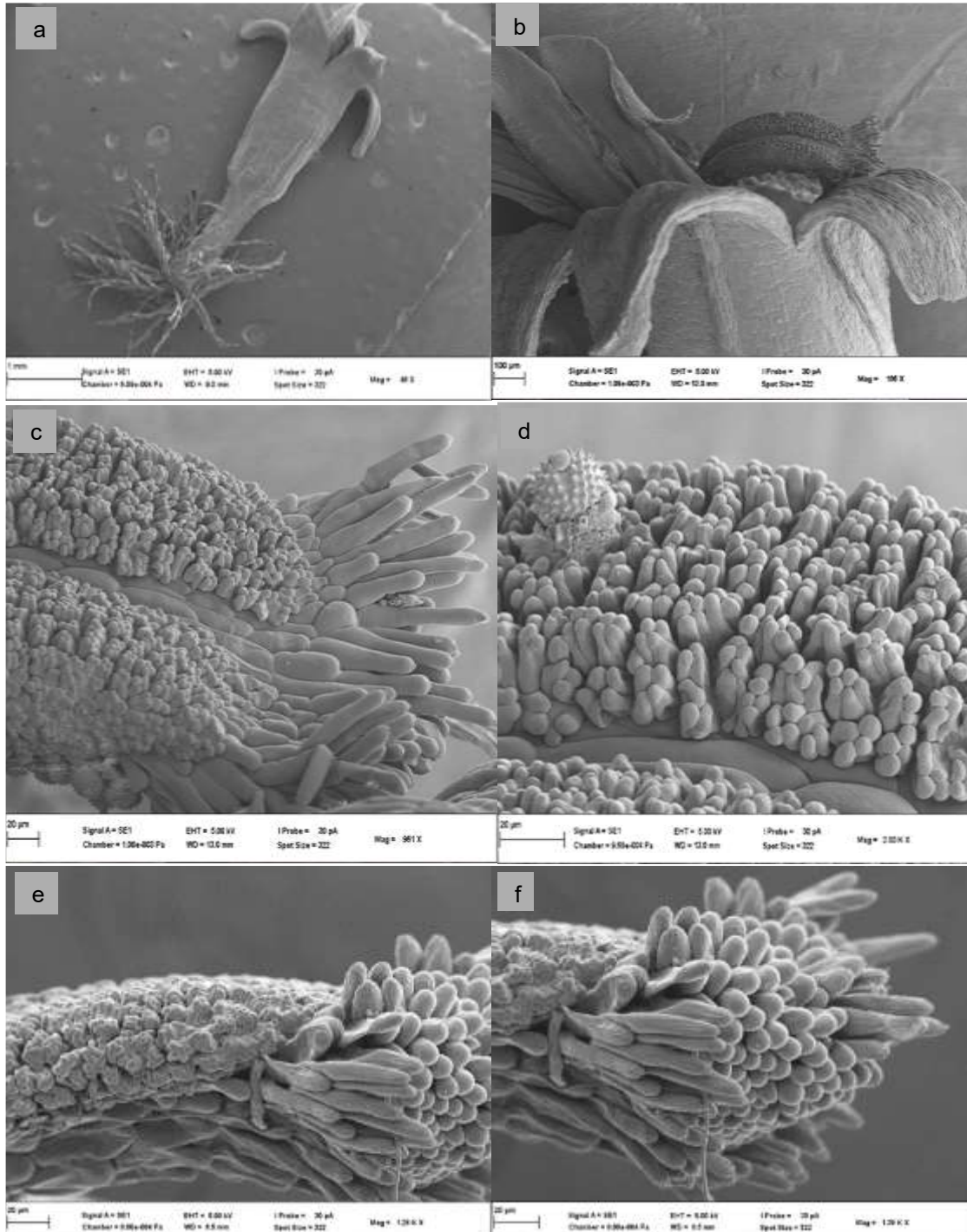


Figure 5. Micrographs of a floret of *E. floribundus*. (a) Calyx showing bristle pappus. (b) Five petals fused at the base. (c, d) Receptor ventro-marginal papillose cells on style branches. The presence of pollen grains on the dorsal side of the branch. (e) The stigmatic papillae cover the inside of the style branch and (f) sweeping hairs cover the external side and apical region.

stem of *E. floribundus* is made up of carbon, oxygen, sodium, magnesium, aluminum, silicon, potassium, calcium and iron (Figure 8a and b). The EDX spectra of the aggregates found in the cortex of the stem showed the

presence of C, O, Na, Al, Mg, Si, K (Figure 9a and b). It is noteworthy to report that there was high content of Na, Si and Al in the cortex and Fe was not detected. The gold peaks were due to sputter coating of the samples.

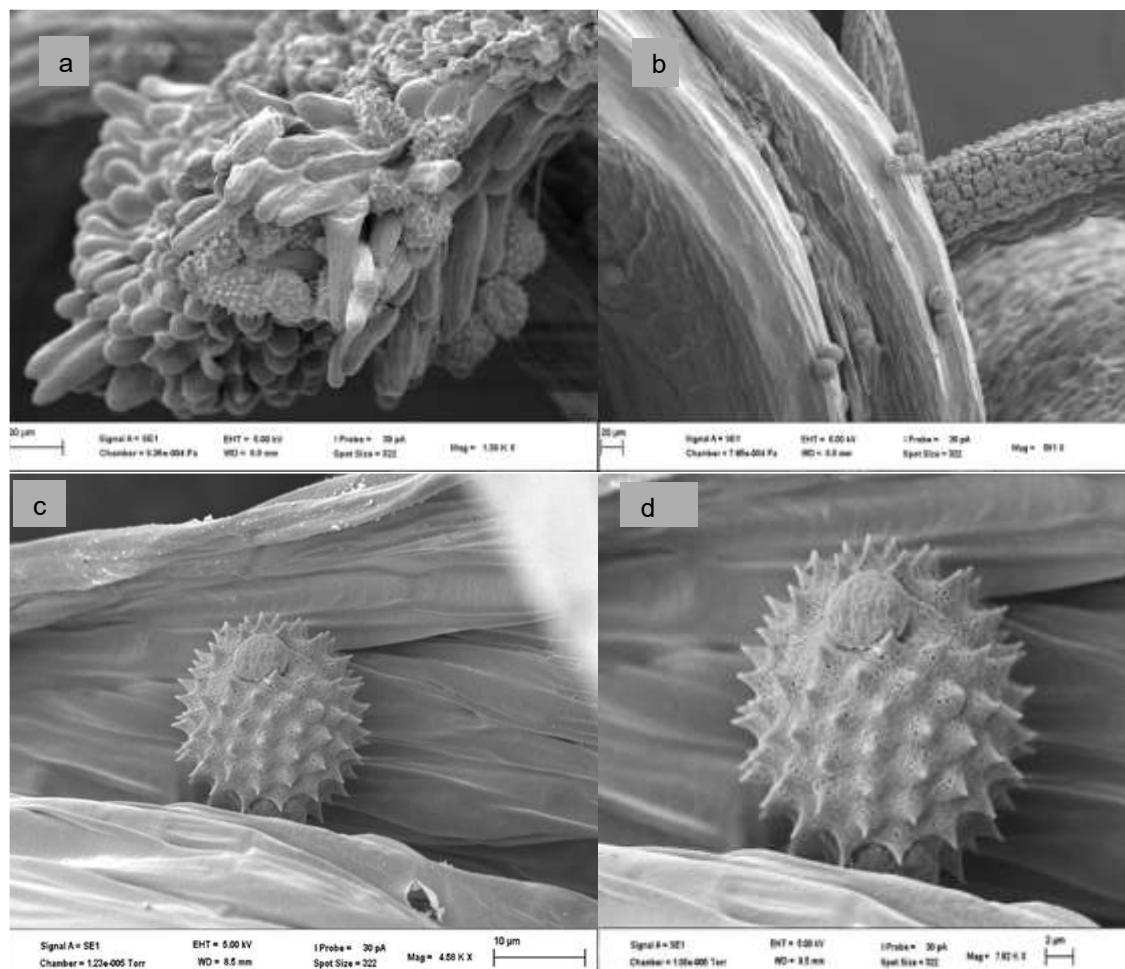


Figure 6. Flower parts of *E. floribundus*. (a) The pollen grains are confined into the tip of the upper portion of the style branch. (b, d) shows the pollen grains relocated on the corolla lobes. The Tricolpate pollen grains with echinate ornamentation adhering to the corolla lobes. Germinating pore of the pollen has swelling protuberance to demonstrate an emerging pollen tube. Note the spikes that attach pollen grain to a pollinator.

Elemental analysis of the crystal-like substance released by the leaf stomata revealed nine elements namely, Si, C, Ca, O, Fe, Mg, K, Na and Al (Figure 10a and b). The unlabeled peaks were present due to the sputter coating of the samples. A total of eleven elements such as C, O, Si, Fe, Al, Ca, K, Cu, Na, Mg and Ti were determined in the crystal deposits found on the lower surface of the leaf tested (Figure 11a and b); although Na, Mg and Ti accumulated to a lesser amount (Figure 11a). The concentrations of different elements present inside the tested plant parts are shown in Table 1.

DISCUSSION

It was found that *E. floribundus* resembled Gymnosperms and the Crassulacean Acid Metabolism (CAM) species in morphology and anatomical arrangements (Strasburger, 1965). The leaves are needle-like in shape making this

plant tolerant to drought and being able to withstand strong winds and frost as is the case with *Pinus*. Although the species studied also possessed needle-like leaves, there was no transfusion tissue. The leaves of *E. floribundus* demonstrated scattered vascular bundles associated with sclerenchyma tissue. Anatomical features common in this plant species included circular to irregular shape of the stem, epidermis with straight anticlinal walls, high density of closed stomata on both sides of the leaf, and arrangement of secretory ducts near the phloem. All these characters observed in the plant studied exhibit xeromorphic characters which are associated with species adapted to arid habitats (Fahn, 1979).

The epidermis of the leaves and stem of *E. floribundus* were covered by a waxy cuticle which is assumed to provide protection against high temperatures, excess irradiation and water loss. Richards et al. (1986) confirmed a similar adaptive advantage of wax deposition under abiotic stress using isolines. They concluded that wax

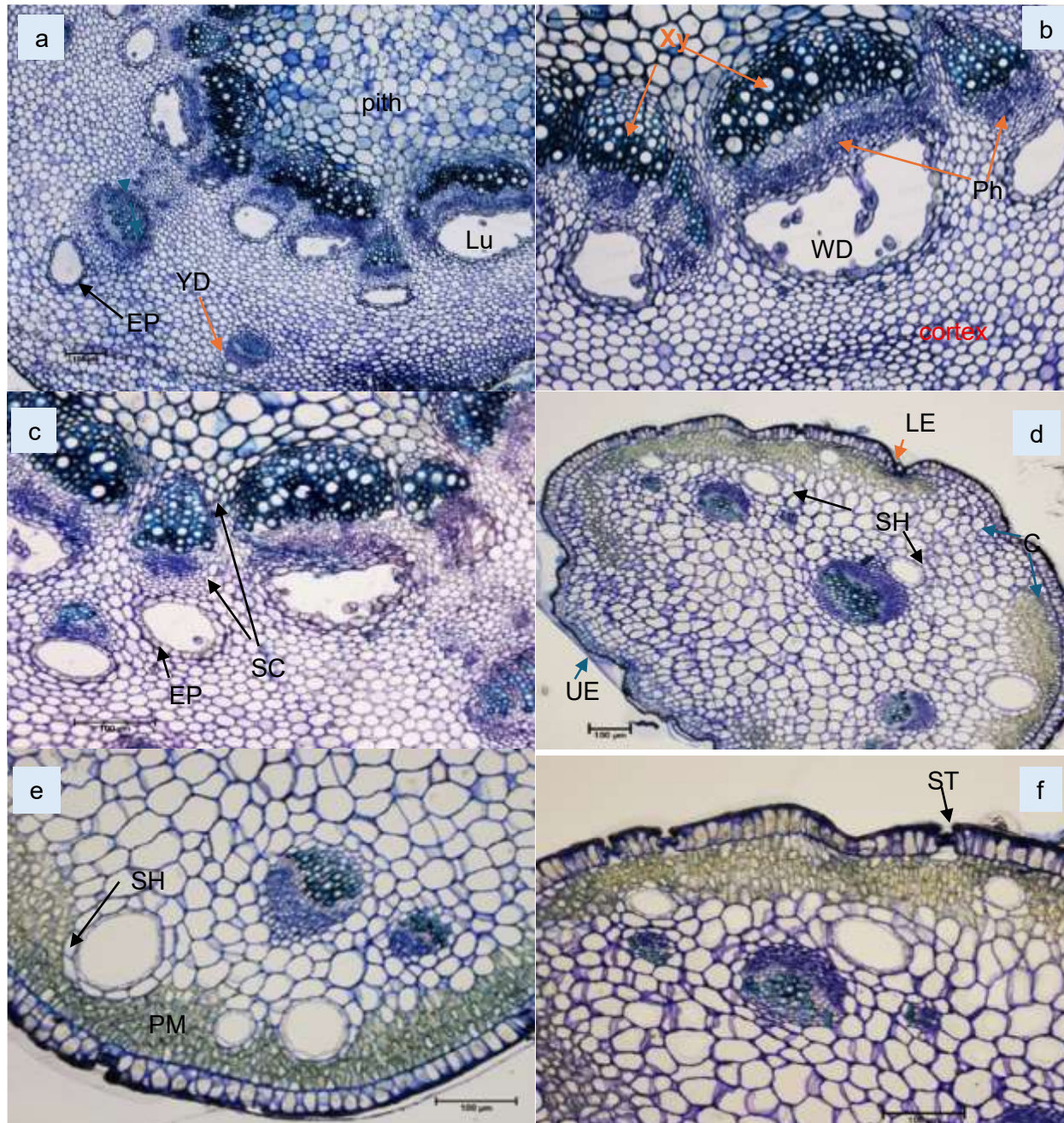


Figure 7. Distribution of secretory ducts in the *E. floribundus* stem: a) Secretory ducts associated with the vascular bundles. Young secretory ducts also appear in the non-conductive phloem of the cortex. b) Epithelial cells in the duct demonstrate irregular walls. c) Secretory ducts assumed to be undergoing division and the epithelium presents a flattened shape. Cross section of a leaf: d) Secretory ducts on the lower part embedded in the phloem cells. e) Palisade mesophyll cells showing flattened epithelial cells and a layer of sheath. f) Thickened abaxial layer with stomata: EP-Epithelium, YD-young duct, WD-wide duct, SC- sclerenchyma, Lu- lumen, Xy- xylem, Ph- phloem, SH- sheath layer, ST- stomata, PM- palisade mesophyll.

deposition can provide thermotolerance especially by presenting insulation against rise in temperature and by reducing the moisture loss from different parts of the plant. Epicuticular waxes consist of a complex mixture of lipids that have been studied extensively after washed off the leaf surface by organic solvents (Ensikat et al., 2000). The fact that waxes formation is a continuous process and not

a terminal phase in the ontogeny of the studied leaves is also significant. These features are assumed to reflect the adaptation mode and the ability of *E. floribundus* in response to the extreme environment.

The *E. floribundus* species is characterized by the presence of internal secretory structures; that is, the secretory ducts. These secretory ducts consist of a lumen

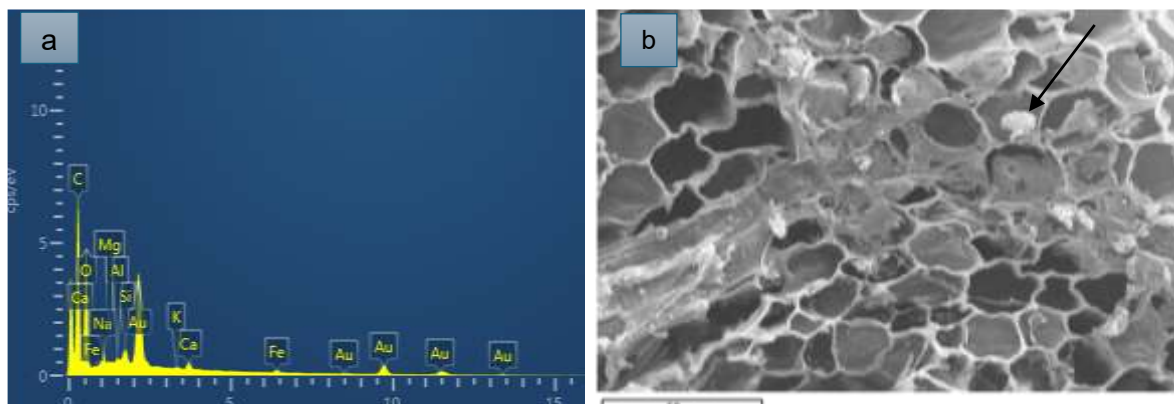


Figure 8. (a) EDX spectra and micrograph of tracheary elements in *E. floribundus* stem. (b) C, O, Na, Al, Mg, Si, K, Ca and Fe were detected. Au peaks are due to sputter coating.

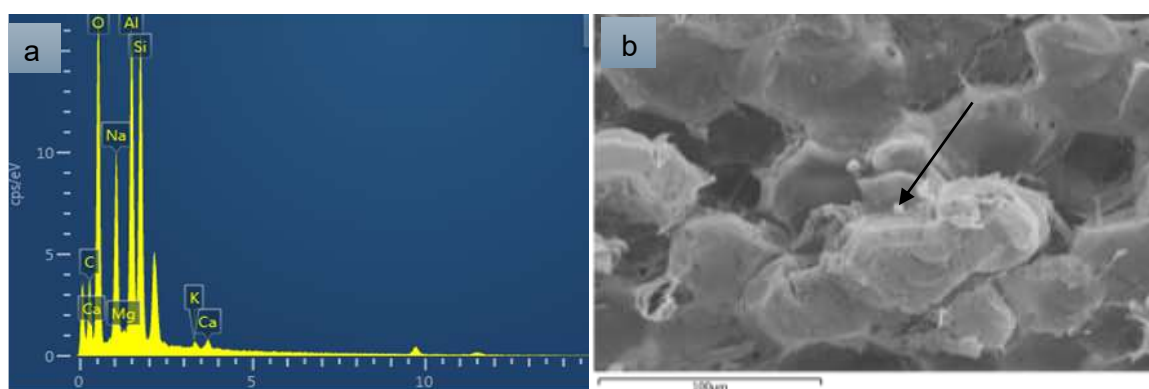


Figure 9. (a) spectra and micrographs of deposits in the collenchyma cortex of the *E. floribundus* stem. (b) C, O, Na, Al, Mg, Si, K and Ca were detected. Note the high content Na, Al and Si (unlabeled peaks are for Au which was used for sputter coating).

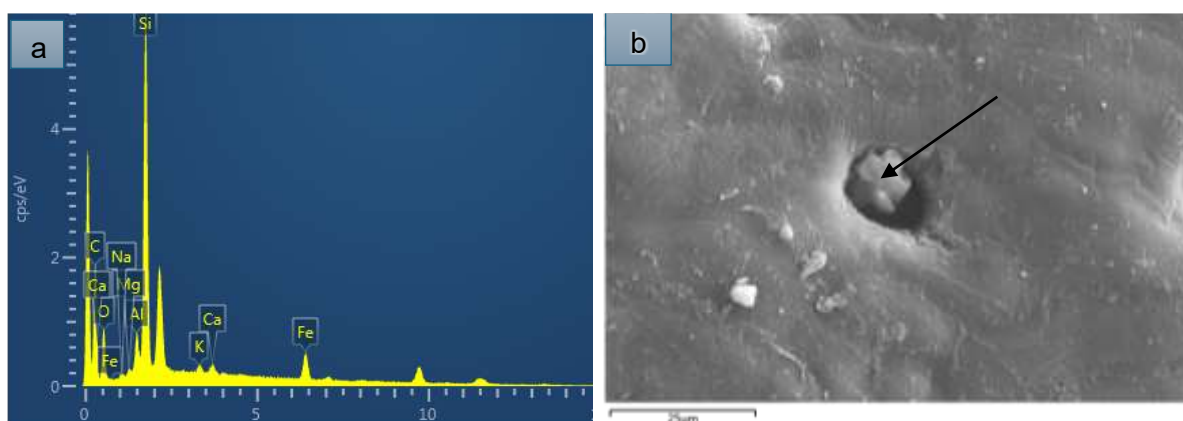


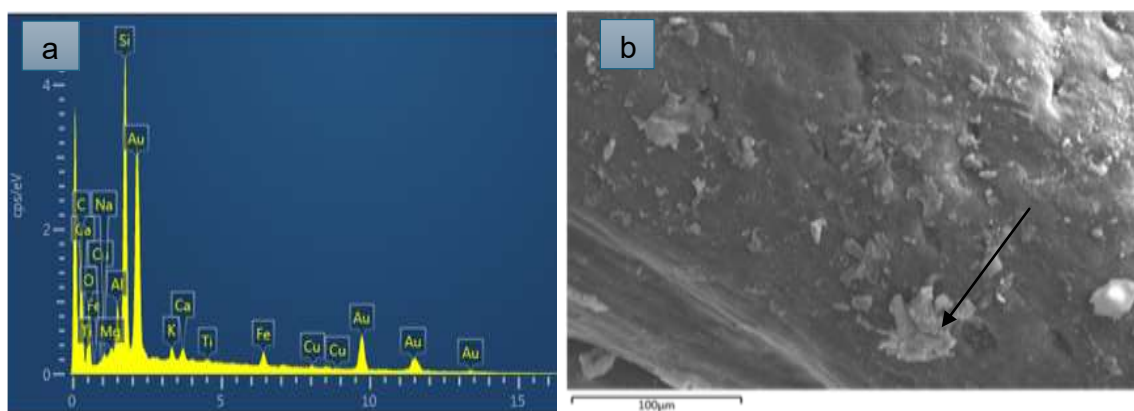
Figure 10. (a) EDX spectra of crystal deposits released by stomata in the *E. floribundus* leaf. (b) The high content of Si and Fe (unlabeled peaks are for Au used for sputter coating).

surrounded by epithelial cells which are assumed to be active in the process of secretion. The interesting structure

and integration of these ducts within the plant body revealed its tight connection to the phloem throughout their

Table 1. Elemental composition and weight percentages.

Element	Figure 8 Weight (%)	Figure 9 Weight (%)	Figure 10 Weight (%)	Figure 11 Weight (%)
Carbon	54.30	19.28	61.74	60.85
Oxygen	42.04	47.61	18.91	21.60
Sodium	1.43	10.22	0.28	0.43
Magnesium	0.14	0.27	0.23	0.32
Aluminium	0.24	11.11	1.41	1.85
Silicon	0.61	10.77	12.25	10.46
Potassium	0.13	0.29	0.42	0.70
Calcium	0.55	0.46	0.53	0.75
Titanium	Not detected	Not detected	Not detected	0.23
Iron	0.56	Not detected	4.23	2.16
Copper	Not detected	Not detected	Not detected	0.64

**Figure 11.** (a) EDS spectra of deposition on epidermal layer of the leaf demonstrating presence of Fe, Ti and Cu. (b) Note high content of Si, Na and Cu (unlabeled peaks are for Au which was used for sputter coating).

distribution in the stem of *E. floribundus*. In the leaves of this plant tested, they were located rather on the lower parts of the mesophyll cells. It is assumed that these ducts keep this location for better protection from the light and overheating as this plant species is reported to be resistant to drought (Gxasheka et al., 2025).

Some secretory ducts in the leaves were associated with the cluster of phloem cells which are reported to handle the sugar rich sap and for duct development hormones (Stefi et al., 2021). The secretory ducts of the plant species studied are assumed to have developed schizogenously where the lumen is formed exclusively through cell walls separation of adjacent cells. They seemed to have originated by separation of cell walls of adjacent cells resulting in a cavity or duct lined with epithelium of resin-secreting cells. Unlike glandular trichomes, which are found on the epidermal layers of leaves and stems of other Asteraceae plants, the resin secretory cells present in *E. floribundus* are endogenous and are assumed to have a longer diffusion pathway to the atmosphere (Langenheim, 2003). The higher inner volume of the secretory duct

network observed in both the stem and leaves of this plant tested are assumed to be directly related to the potential to produce resin. Their high distribution also appeared to be likely for its essential oil production, unlike secretory structures of well-known essential oil producing species. The ducts are reported to produce and exude oleoresin (Fahn, 1979), an effective terpenoid based chemical defense against insects and pathogens (Keeling and Bohlmann, 2006). The SEM examination of stem sections of the plant studied showed that the resin occurs partly as an exudate on the surface. The plant studied also produces essential oil but there is no clear evidence of whether it is found in the intracellular or extracellular position of the plant before appearing in the ducts.

The other type of secretory duct observed in this plant species is assumed to be induced in response to mechanical injury. Some authors reported that several external stimuli like wounding, insect attack and pathogen infestation induced the formation of traumatic resin ducts (Nagy et al., 2000; Chen et al., 2018). The formation of these traumatic ducts appeared to be strategically

positioned in a deliberately injured stem of *E. floribundus*. A mechanical injury to the bark is assumed to immediately exude resin with sap to coat the cut surface. The secretory ducts are reported to produce a highly diverse array of chemical compounds in complex mixtures such as essential oil, resins and mucilages (Pagni et al., 2003; Prado and Demarco, 2018).

E. floribundus capitulum is characterized by having a calyx which developed as bristle pappus. This is one of the characteristic features of many Asteraceae species (Kalmuk et al., 2018). The presence of sweeping hairs at the very tip of the style of *E. floribundus* and their arrangement could indicate, according to Erbar and Leins (2000), a pump pollen presentation mechanism or a brushing mechanism. The pollen presentation is assumed to be correlated with the arrangement of sweeping hairs (Erbar and Leins, 2010, 2015). It is assumed that as the style elongates within the anther tube, the sweeping hairs push or brush the pollen out of the anther tube. Such a pollen presentation pattern observed in this plant seems to be an indicative of secondary pollen presentation functional through brush mechanism (Erbar and Leins, 2010). Hong et al. (2008) reported that the members of Asteraceae exhibited the phenomena of secondary pollen presentation. Similar observations were reported by other authors on the long hairy styles found in perfect florets of *Lessingianthus grandiflorus* and *Lucilia lycopodioides*. They stated that these species exhibited sweeping hairs which had a significant role in pollen presentation where pollen is brushed through the anther to expose it to the pollinator agents (Leins and Erbar, 2006; Hong et al., 2008). However, Erbar and Leins (2021) reported that a pump and a brushing mechanism can be combined.

The stigmatic papillae are located inside the style branches of *E. floribundus*. Similar location of stigmatic papillae has been reported in *Mutisia* species by Torres and Galetto (2007). They demonstrated a definite and permanent distribution of papillae, with the receptive ones restricted to the inner side of the lobes, whereas the outer part of the lobes is covered by non-receptive, pollen-collecting papillae. Unlike the plants with the primary pollen presentation, where pollen is directly delivered to pollinators from anthers, all the species in Asteraceae family relocate pollen from the anthers to other specialized floral structures (El Ottra et al., 2024).

A total of nine elements, C, O, Na, Al, Mg, Si, K, Ca and Fe were detected inside the stem of the plant species tested by using EDX analysis. It is noteworthy to report that there was high content of Na, Si and Al in the collenchyma cells of the stem. The crystal deposition associated with the stomata of leaf epidermis also revealed high concentration of Si. The relatively high concentration of Si in vegetative parts of Asteraceae plants was reported by many authors (Hodson et al., 2005; Piperno, 2006; Katz et al., 2014). They stated that Si has an adverse effect on insect herbivory, for example, through the accumulation of solid silica particles in the plant which are thought to

reduce herbivore feeding and delay digestion. The protective effect of Si deposition bodies on the leaf epidermis is reported to also enhance plant tolerance against abiotic and biotic stresses, such as UV tolerance, salinity, pathogen and fungal attack (Yao et al., 2011; Siddiqui et al., 2022). Massey and Hartley (2009) reported that Si deposition increases roughness of plant tissue and thus reduces palatability and digestibility for herbivores. It can, therefore, be assumed that high concentration of Si present in *E. floribundus* species plays an important role in repelling herbivores. This may confirm the report by Gxasheka et al. (2025) on unpalatability of this plant to herbivores. Carbon and O were the most abundant elements absorbing these elements from the atmosphere as CO₂, and from the soil as H₂O (Allakhverdiev et al., 2009). Aluminium, which was present in the collenchyma cells of the stem of *E. floribundus*, is not an essential element for plants and can cause toxicity upon high accumulation (Muhammed et al., 2019). However, its presence is due to the usage of Aluminium stubs. Ca, which is believed to play a pivotal role in triggering stomatal closure, accumulated to a lesser extent (Kudla et al., 2018). This could suggest why the stomata observed in the leaves were tightly closed. From the study, it was revealed that elements such as Mg, K and Cu accumulated to a lesser extent in the plant parts tested. Although Titanium was absent in other parts tested, it was present in trace amount in the epidermal layer of the leaves. The presence of Ti and Cu in the leaves may be due to root uptake from the soil or through leaf surfaces when these particles are deposited. Fe demonstrates an appreciable presence in this plant and is an essential microelement for plants (Aung et al., 2024). It forms a pillar of many enzymatic reactions influencing photosynthesis and respiration (Kar and Panda, 2020). Na exhibited high concentration in the cortex. Although it is not an essential element in plants, it can be beneficial by aiding in the metabolism and synthesis of chlorophyll particularly when K is deficient (Mian et al., 2010).

Conclusion

Secretory ducts have emerged as the main secretory system of *E. floribundus*, and their presence is widely distributed throughout the stem and leaves. According to our results it has been established that there is an obvious relationship between the secretory ducts and vascular bundles of the research plant. They seemed to have developed when the vascular bundles had almost completed their development. In this work, it is shown that one of the promising areas of research could be the identification of secondary metabolites secreted by these ducts. The present study on structural adaptation and exudation of resin through the secretory ducts of *E. floribundus* could be a guideline for future investigations. Furthermore, the current investigation on elemental

concentration of this plant species could be useful for future research and preparation of drugs for medicinal properties.

ACKNOWLEDGEMENT

The authors are thankful to Govan Mbeki Research and Development Centre for the financial support which enabled the successful completion of the research.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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