

Siphonochilus aethiopicus (Zingiberaceae): observations on floral and reproductive biology

K.D. Gordon-Gray*, A.B. Cunningham and G.R. Nichols

Department of Botany, University of Natal, P.O. Box 375, Pietermaritzburg, 3200 Republic of South Africa; Institute of Natural Resources, University of Natal, P.O. Box 375, Pietermaritzburg, 3200 Republic of South Africa and Department of Parks, Recreation and Beaches, P.O. Box 3740, Durban, 4000 Republic of South Africa

Accepted 20 January 1989

A taxonomic revision for the Flora of Southern Africa of *Siphonochilus* (Zingiberaceae) awaits publication (R.M. Smith, RBG, Edin., pers. comm. to ABC, 1987). In this revision the two southern African species, *S. aethiopicus* (Schweinf.) B.L. Burtt and *S. natalensis* (Schltr. & Schum.) Wood & Franks will be united. For the purposes of this article this conspecificity is assumed. *S. aethiopicus* has a distribution in Africa southwards from Senegal and Ethiopia to the Transvaal. Further south wild populations are not now known, the species having disappeared from the natural flora of Natal. Rhizomes are extensively used in traditional African medicine and cultural practices. Floral and reproductive biology is poorly documented, but important if cultivated stocks in southern Africa are to be maintained. Monitoring of plants under cultivation and semi-natural conditions did not support the record of polygamy within the species. One type of flower only was produced by an individual rhizome. Bisexual flowers may mature to fruits containing viable seed that will germinate *in situ*. Ovaries of female flowers did not develop, suggesting apomixis does not operate in seed production. The internal surfaces of the staminodial tubes of bisexual flowers bore scattered glandular trichomes; those of female flowers densely placed multicellular papillae. Bisexual and female flowers are thus strikingly different in detailed structure as well as in general morphological form.

'n Taksonomiese oorsig van *Siphonochilus* (Zingiberaceae) vir die Flora of Southern Africa wag tans op publikasie. (R.N. Smith, RBG, Edin., pers. kommunikasie met ABC, 1987). In hierdie oorsig sal die twee suidelike Afrika-spesies, *S. aethiopicus* (Schweinf.) B.L. Burtt en *S. natalensis* (Schltr. & Schum.) Wood & Franks, verenig word. Vir die doeleindes van hierdie artikel word ko-spesifisiteit aangeneem. *S. aethiopicus* se verspreiding in Afrika strek suid van Senegal en Ethiopië tot in die Transvaal. Die spesie is nie verder suid bekend nie aangesien dit van die natuurlike flora van Natal verdwyn het. Risome word wyd in die tradisionele Afrika medisinale en kulturele praktyke gebruik. Blom- en voortplantingsbiologie is sleg gedokumenteer, maar dit is 'n belangrike aspek indien verboude voorrade in suidelike Afrika in stand gehou moet word. Waarneming van plante onder verbouing en semi-natuurlike toestande het nie die rekord van poligamie in die spesie ondersteun nie. Slegs een tipe blom is deur 'n enkele risoom geproduseer. Biseksuele blomme mag vrugte waarvan die saad *in situ* sal ontkiem, tot rypwording bring. Vrugbeginsels van die vroulike blomme het nie ontwikkel nie en dit dui daarop dat apomixis nie by saadproduksie betrokke is nie. Die binneoppervlak van die staminodiale buise van biseksuele blomme het verspreide klieragtige trigome gedra; dié van die vroulike blomme dig-gerangskikte multiselulêre papille. Biseksuele en vroulike blomme verskil dus ooglopend in gedetailleerde struktuur asook in die algemene morfologiese vorms.

Keywords: Cultivation, *Siphonochilus*, southern Africa, Zingiberaceae

*To whom correspondence should be addressed

Introduction

Burtt (1982) established that the name *Siphonochilus* Wood & Franks was synonymous with *Cienkowskia* Schweinf. non Regel & Rach = *Cienkowskiella* Kam and must be adopted as the legitimate genus for African elements of *Kaempferia* L. (Zingiberaceae). Kam (1980) had recognized these African plants as forming a distinct group distinguished from the kaempferias of Asia by a combination of six well-marked characters.

For southern Africa, Gibbs-Russell *et al.* (1985) listed two species, *S. aethiopicus* (Schweinf.) B.L. Burtt and *S. natalensis* (Schltr. & Schum.) Wood & Franks. Morphologically these species are indistinguishable except that polygamy has been recorded for the latter (flowers bisexual and female, Wood & Franks 1911c: 115), but never for the former where flowers are bisexual

only. A revision of *Siphonochilus* for the Flora of Southern Africa has been completed and awaits publication (R.M. Smith, RBG, Edin., pers. comm. to ABC, 1987). In this revision the species named above will be united. For the purposes of this article, this conspecificity is assumed.

There are other species of the genus in Africa, all from further north (Burtt 1982). These are not relevant here, except to report that for none is polygamy known.

S. aethiopicus has a distribution southwards through Africa from Senegal and Ethiopia. Plowes & Drummond (1976) record it for Mozambique and the eastern highlands of Zimbabwe; Compton (1976) for Swaziland (under *Kaempferia ethelae* J.M. Wood); Onderstall (1978, 1984) and Davidson (pers. comm. to ABC, 1987) for the Transvaal. Further south it is not now known to exist in the wild. Earlier authors recorded its presence

(as *S. natalensis*) at Ngoye and Inanda (Wood & Franks, 1911a, c) and there have been tentative suggestions of its possible occurrence in some of the river valleys south of Durban and into the Transkei (Burt 1982 reporting Sanderson 1868; also unsubstantiated verbal statements).

Rhizomes are important in traditional African medicine and in magi-medicinal cultural practices. Since the middle of the last century there are records of traffic and trading in the plants from sites of occurrence to areas of utilization. Also, transplantation from natural populations to the vicinities of habitations, either for cultivation or for the magical protection of the inhabitants, was commonplace (Wood & Franks 1911c; Webb & Wright 1979, 1982; Burt 1982; Cunningham 1988, 1989). Recent findings indicate that the bulk of the material now traded originates from the Transvaal and perhaps further east (Cunningham 1988). Interference with natural populations has made southernmost distributional limits uncertain and depredation has resulted in elimination of the species from the natural flora of Natal and KwaZulu. In consequence, it is important to maintain stocks presently under cultivation and from these and from the natural populations further to the north, to attempt to derive botanical details still unknown. Particularly is information in the field of reproductive biology significant, as, because of the extensive usage of rhizomes in herbal medicine, commercial cultivation will surely be necessary to maintain supplies and to keep prices reasonable. Burt (1982) expressed the need for a more critical investigation of the stamenless female flowers. It is also important to substantiate '.... that both the female and the perfect flowers were found on the same plant, but not at the same time....' (Wood & Franks 1911c: 115).

Materials and Methods

Plants monitored

Five stands of plants were kept under observation. Table 1, A-E gives details of the known history, present location and treatment under cultivation of these stands, together with individual findings derived from study over variable periods of time, of the plants they comprised. For stand E, clonal relationship of the components is very unlikely; for the remaining stands no inferences may be drawn since no information on the reproductive relationships of the plants within each stand exists.

General procedure

Monitoring of the stands took place at intervals; for stand A inspection was daily, for other stands not so frequent. Flowers and fruits were examined as development took place.

Formal descriptions based on information derived from these examinations are given at the end of the paper, but these cover only features requiring modification or elaboration or that are previously undescribed. For rhizomes bearing bisexual flowers, details of the reproductive cycle and the duration of its phases are

recorded. Insufficient material was available to make this worthwhile for stands C and D.

Results and Discussion

Floral structure

Bisexual flowers

The structure of these flowers has been well described and illustrated (Wood & Franks 1911a, b; Kam 1980; Burt 1982). Their most conspicuous feature is formed by the petaloid staminodial whorls situated above the thick-walled corolla tube and lining this. The lower half of these whorls forms a split, rounded tube lined by downwardly directed, stalked glandular trichomes that decrease in frequency into the corolla tube (see Figure 1). The upper half expands into the two lateral 'petals' and bilobed 'labellum'. There is also the posteriorly placed stamen.

Some flowers from rhizomes cultivated in Edinburgh developed an additional small lobe between the two main lobes of the 'labellum' (Burt 1982, Fig. 1G). This additional lobe was not represented in any of the flowers checked by us (stand A, 35 taken at random in 1986, all 61 produced the following year; stand B, 2 taken at random 1986, repeated 1987).

All flowers dissected contained a functional anther, sessile on the broad, petaloid filament, the connective of which projects from the staminodial tube and overarches the anther and stigma. The positional co-ordination of these last-named organs, ensured by enclosure of the upper part of the style in a centrally placed narrow channel in the broad filament, has not been adequately stressed before.

Early descriptions (Wood & Franks 1911a, b) do not mention the two oval, white, densely textured glands compactly set in sterile tissue towards the apex of the ovary. These epigynous glands are illustrated by Kam (1980, Fig. 3E) and by Burt (1982, Fig. 1J, I). We found them always present.

Female flowers

The female flower was illustrated and described by Wood & Franks (1911a, b), but its structural features are less known than those of the bisexual type. We have dissected only six, from different rhizomes, grown under pot culture. It is probable the full range of variability of these flowers is not yet known. All we observed differed markedly in shape from the bisexual type and could be recognized as different on superficial observation, even at a distance. It is notable that flowers from different rhizomes may differ quite markedly in size. There was no difference in construction, however. The unsplit staminodial tube is the most conspicuous feature. Wood & Franks (1911c, p. 115) described it as 'closed almost to the apex, the aperture (was) very narrow...'. We did not find the tube or the mouth appearing so narrow. The rough papillate lining is worthy of note. The papillae sometimes run in vertical lines; their multicellular construction is quite distinct from the stalked, glandular trichomes of the bisexual staminodial tube (see Figure 1). Wood & Franks (l.c.) described this lining as '... a

Table 1 Details of stocks of *Siphonochilus* monitored and the more important findings derived from a study of the stocks

	Identification letter				
	A	B	C	D	E
History and possible provenance of stock	Gift to family of grower, about 60 years ago. Possibly from Zululand or Eston, Natal.	Gift from garden at Mtunzini in 1980. Possibly from Ngoye.	Gift from Umlazi herbalist, about 1984. Provenance unknown.	Purchased from plant vendor, 1987. Provenance unknown.	Natural populations and plants from these populations under semi-natural cultivation. Eastern Transvaal, 1973 to 1987.
Present location	For past 20 years cultivated at Escombe (Queensburgh); previously at Malvern (both slightly inland from Durban).	Durban	Durban	Pietermaritzburg	Hoedspruit (alt. 550 m); Tzaneen (alt. 760–850 m).
Cultivation	Natal grey sand; E-facing aspect; good drainage. No disturbance by lifting for 20 years. No watering, fertilizing, or other cultural practices.	Well drained, compost-rich soil; 3-weekly watering; fertilization in spring (500 g granular 2:3:2 mixed with compost over rooting area). No lifting during past 3 years.	Favourable pot-culture; no lifting during past 3 years.	Favourable pot-culture under greenhouse conditions.	Natural, or near natural conditions in experimental plots; natural soils.
Flower type	Bisexual only 1986 — 112 flowers produced (35 taken at random for dissection). 1987 — 61 flowers produced (all checked). Grower recalls only bisexual type flowers throughout history of cultivation.	Bisexual only during 3 years of observation.	Female only during 3 years of observation.	Female only; produced soon after planting; buds probably set before rhizomes lifted.	Bisexual, but monitoring of every flower was not possible. There was variation in size, colour, and to a lesser degree in shape in flowers from different rhizomes; never observed for an individual rhizome.
Fruit set: seed germination	Mature fruits (underground): seed germination <i>in situ</i> .	Mature fruits (above ground): collected seed viable (germination took 11 mths).	No fruits or seeds known.	No fruits or seeds known.	Mature fruits (above ground): seeds germinated <i>in situ</i> and under cultivation (planted seed took 2 mths to germinate).
Seedling growth	Poor <i>in situ</i> with damping-off frequent; excellent if transplanted and favourably maintained.	Grown only under cultivation; progress good with favourable treatment.	Seedlings unknown.	Seedlings unknown.	Less rapid <i>in situ</i> than when grown under cultivation.

thickened or somewhat furry substance...'. They also (Wood & Franks 1911a) described the gynoeical whorl as '... of hermaphrodite flower'. But the style is much

shorter and unconfined, the stigma smaller and quite differently shaped and positioned from that of the bisexual flower (see formal description).

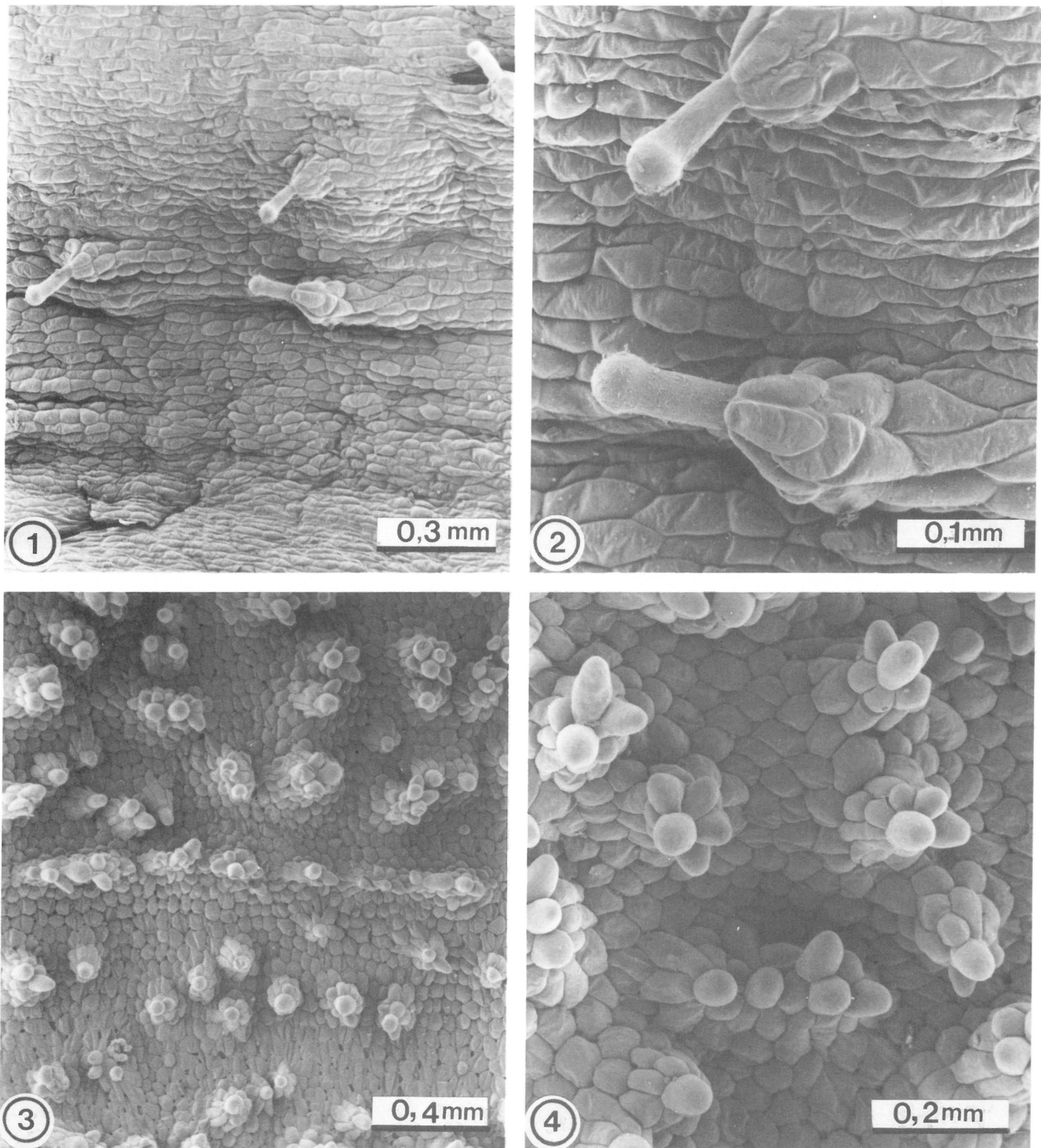


Figure 1 *Siphonochilus aethiopicus*: portions of staminodial tubes showing sculpturing of inner surface. (Note: bases of tubes left; apices right). 1, 2 — bisexual flower showing stalked, glandular trichomes; 3, 4 female flower showing papillae. (Specimens were mounted on specimen stubs and sputter coated with Polaron E 5100 sputter coater, and viewed on a Hitachi S 570 S.E.M. at 5 kv).

Reproductive cycle

The complete reproductive cycle is known only for rhizomes that produce bisexual flowers, but details of the vegetative organs, flowering and the growth cycle apply also to rhizomes that produce female flowers.

Vegetative organs and growth cycle

Rhizomes grow either on the soil surface, or

underground to a depth of 150 mm. Widely spreading lateral roots with marked tuberous swellings are developed. During the unfavourable season stands are not obvious above ground, but with the advent of the spring rains aerial shoots develop, shortly before, or contemporary with, buds. The aerial shoots continue to elongate until after flowering is complete, but after the December solstice growth gradually ceases. Yellowing commences quite suddenly, usually during April, and by

May the aerial shoots have collapsed. Plants are reported as being remarkably pest free.

Flowering

One of the six important differences by which Kam (1980) differentiated *Siphonochilus* from *Kaempferia* was that in the former, the inflorescence axis develops separately from the leafy shoot. This was apparent at flowering, for buds emerged directly from the ground 10–20 mm from aerial shoots. Excavation exposed the rhizome to show the abbreviated, racemose, 4–5-flowered inflorescence axis, developed from tissue underlying, but terminal in relation to, that which had produced the nearest vegetative shoot. Buds were visible above ground usually 5–8 days before opening. Expansion into open flowers takes place during the night. Each flower is reported to last only one day (Onderstall 1978; Davidson, pers. comm. to ABC, 1987) but occasional flowers may last till a second morning.

Flowering commences mid to late October, and continues to the end of December. It is unusual for flowers to be developed at other times, but transplanting of rhizomes with buds already set during a previous resting season causes immediate development of these buds.

Pollination

Opinions differ concerning the odour of the flowers, from unperfumed (one person only) to '... a haunting, spicy fragrance reminiscent of ginger' (Onderstall 1978). Consensus favours a delicate scent particularly evident in the late evening and morning.

The only insects noted in constant association with the flowers were black dipterids (± 2 mm in length) resting (?) in large numbers on the petaloid staminodial lobes. Presumably this is the 'Mucid Fly' seen by Wood & Franks (1911a) and the insect said to enter the throat of the flower by a Transvaal observer (Davidson, pers. comm. to ABC, 1987). Dissections of deteriorating flowers showed no dead dipterids within staminodial or corolla tubes, but minute translucent to milky-white larvae with black points were frequently present in the stylar channel near the anther. It is not known whether these are a stage in the dipterid life cycle. The downward-pointing glandular hairs of the staminodial tube seem likely to prevent insect escape; nevertheless occasional black ants are reported to creep in and out of flowers grown in Durban.

Unless apomixis operates to produce viable seed, pollination must take place. Self-pollination seems likely since all the fading flowers dissected had pollen in contact with the receptive stigmatic surface. This transference possibly takes place at time of collapse of the staminodial lobes.

Capsule and seed development

Ovary enlargement and capsule maturation is rapid. Seed is mature 5–8 weeks after flowering. If the capsules are underground, the soft parts decay leaving a fibrous skeleton which eventually disintegrates; if

exposed they dry and dehisce. Some rhizomes flower profusely yet mature few, if any, fruits. The seeds remain viable for at least 1 year.

Seed germination and seedling survival

Seeds germinated *in situ*. The seedlings penetrated through the decaying fruit walls. Growth was relatively slow and damping-off took place. When individually potted and given reasonable care, seedlings grew rapidly and in the second year of growth were hardly distinguishable, except for rhizome development, from mature plants. Seedling structure is shown in Figure 2. From an early stage the tuberous root(s) are well developed.

Conclusions

Monitoring studies have shown:

1. that rhizomes produce either bisexual or female flowers. No evidence was obtained that suggests both flower types may develop from an individual rhizome.
2. that bisexual flowers set mature fruit and viable seed which germinates either *in situ*, or when planted under cultivation. The reproductive cycle of rhizomes producing bisexual flowers is thus capable of completion in nature.
3. that female flowers lack a functional male organ and are distinctive in form from the bisexual flowers. There is size variability in the female flowers produced from different rhizomes.
4. that female flowers do not produce mature fruits. There was no enlargement of the ovary, which is suggestive that apomixis does not operate in seed production in either the female or the bisexual flowers.

It is important that study of the rhizomes producing female flowers be continued. Few rhizomes were available and these have been monitored for only 4 years. It is also essential that wild populations in the eastern Transvaal be carefully checked for the presence of stamenless flowers. Seed should be studied during development for the possible presence of an aril. Such an outgrowth was not observed in mature seeds.

Eventually karyotypical studies should be undertaken. These may reveal information on polygamy within the family.

Formal descriptions

Bisexual flower and fruit (information derived from stands A & B)

Anther 12–14 mm long, slightly curved, clearly bilobed, dehiscence longitudinal, releasing sticky pollen, grains large, accrescent into clumps. *Style* ± 65 mm long, free below, eventually passing into a narrow central channel of the filament where it is securely held behind the anther lobes. *Stigma* immediately above and overarched the anther, the receptive surface directed upwards, hypocrateriform (salver-shaped) in face view with an asymmetric, laterally elongate cavity leading back into the hollow style, obsoletely 3-lobed, the lobes variable in development, never strongly marked, infundibuliform

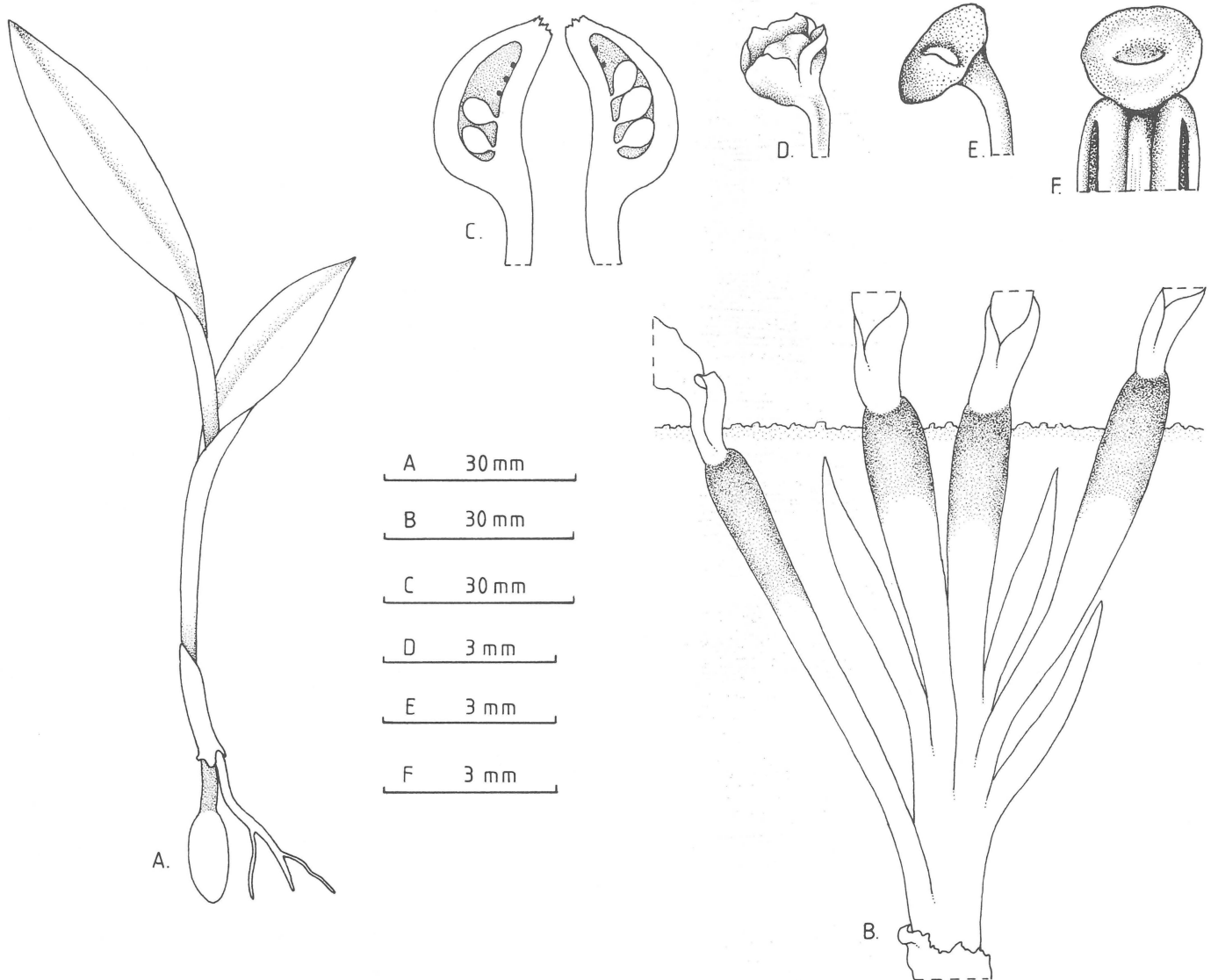


Figure 2 *Siphonochilus aethiopicus*. (A) young seedling germinated *in situ*; (B) inflorescence branching (underground), bract of oldest flower fallen away (stippling represents bright maroon-pink coloration of pedicels); (C) longitudinal section through one loculus of developing ovary showing some ovules maturing, others infertile; (D) stigma of female flower; (E, F) stigma of bisexual flower from side and front respectively, showing in front view the close relationship with the anther. (A, B, C, E and F from Stand A; D from Stand D).

(funnel shaped) in side view. *Ovary* subterranean to slightly exposed, a cherry-sized, bright maroon capsule at maturity that, if underground, decays and disintegrates; if exposed dries, darkens and dehisces. Up to 15 fruits produced by 1 rhizome, usually 2-4 only. Seeds up to 30 per capsule, 2-3 mm in diameter, pale cream to brownish; viable for ± 1 year: germination period ± 2 months.

Female flower (information derived from stands C & D) *Flowers* variable in size from different rhizomes; roughly actinomorphic (contrasting with the zygomorphy of the $\text{\textcircled{f}}$). *Calyx*, *corolla* as for $\text{\textcircled{f}}$. *Staminodial whorl* an unsplit, erect tube, 63-75 mm long, yellow to greenish-yellow, broadening from narrower base to mouth $\pm 5-7$ mm in diameter, inner surface roughly papillate (papillae multicellular), 4 petaloid lobes expanded from

mouth of tube, 1 or 2 bifid (giving the impression of 5-6 lobes), erect to slightly outward-spreading, narrowly oblong, obtuse, ± 32 mm long, 6-18 mm wide, bright deep purplish-pink paling towards bases. *Stamen* 0. *Ovary*, ovules and epigynous glands of $\text{\textcircled{f}}$. *Style* 23-27 mm long, centrally placed in corolla tube. *Stigma* symmetrically to asymmetrically 3-lobed, crateriform, receptive surface upward-facing, pale pink. Mature fruit and seed unknown.

Acknowledgements

We wish to thank all who have assisted in this project, either by tending and observing plants, or with preparation of the script. We also thank Professor J. van Staden for facilities afforded us by the Department of Botany, University of Natal, Pietermaritzburg. Mr V. Bandu of the Electron Microscope Unit, University of

Natal and Mrs L.S. Davis very competently prepared Figures 1 and 2 respectively.

References

- BURTT, B.L. 1982. *Cienkowskiella* and *Siphonochilus* (Zingiberaceae). *Notes RBG Edinb.* 40 (2): 369–373.
- COMPTON, R.H. 1976. The flora of Swaziland. *Jl S. Afr. Bot. Suppl.* Vol. 11: 147.
- CUNNINGHAM, A.B. 1988. An investigation of the herbal medicine trade in Natal/KwaZulu. Investigational report No. 29, Institute of Natural Resources, Univ. of Natal.
- CUNNINGHAM, A.B. 1989. Conservation and utilization of *Siphonochilus natalensis*. *S. Afr. J. Bot.* (in press).
- GIBBS RUSSELL, G.E., REID, C., VAN ROOY, J. & SMOOK, L. 1985. List of species of southern African plants. *Mem. bot. Surv. S. Afr.* 51: 133.
- KAM, YEE KIEW. 1980. Taxonomic studies in the genus *Kaempferia* (Zingiberaceae). *Notes RBG Edinb.* 38: 1–12.
- ONDERSTALL, J. 1978. *Kaempferia aethiopica* — wild ginger. *Veld & Flora* 1978: 43–44.
- ONDERSTALL, J. 1984. Transvaal lowveld & escarpment (including Kruger National Park). S.A. Wild Flower Guide, 4th Series, Botanical Society of South Africa.
- PLOWES, D.C.H. & DRUMMOND, R.B. 1976. Wild flowers of Rhodesia. Longman, Salisbury.
- SMITH, R.M. Revision of Zingiberaceae for Flora of southern Africa. (Manuscript unpublished; in keeping of Botanical Research Institute, Pretoria).
- WEBB, C. de B. & WRIGHT, J.B. 1979. The James Stuart Archive of recorded oral evidence relating to the history of the Zulu and neighbouring peoples. Vol. 2, p. 84, Univ. of Natal Press, Pietermaritzburg.
- WEBB, C. de B. & WRIGHT, J.B. 1982. The James Stuart Archive of recorded oral evidence relating to the history of the Zulu and neighbouring peoples. Vol. 3, p. 263, Univ. of Natal Press, Pietermaritzburg.
- WOOD, J.M. & FRANKS, M. 1911a. *Siphonochilus*. In: Natal plants, Vol. 6(3), tab. 560–561.
- WOOD, J.M. & FRANKS, M. 1911b. *Siphonochilus*. *Kew Bull.* 1911: 274–275.
- WOOD, J.M. & FRANKS, M. 1911c. *Kaempferia natalensis* Schltr. & Schum. *The Naturalist.* (J. Natal Sci. Soc.) 1: 112–115.