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Cyperus stroudii (CYPERACEAE), a new species from Ascension Island, South Atlantic Ocean

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Abstract

Material from the *Cyperus appendiculatus* group was collected from Ascension Island and compared using a common garden study and to herbarium specimens from throughout the geographical range. *Cyperus stroudii* is described as a new species, known only from Ascension Island in the South Atlantic Ocean, it closest relative is *C. appendiculatus* also native to Ascension Island and Brazil. *Cyperus stroudii* differs from *C. appendiculatus* in its dwarf habit and other morphological characteristics, and these characteristics are retained under common environmental conditions indicative of genomic differences.

Keywords: Cyperaceae, endemic species, islands, speciation

Introduction

Ascension Island, a UK Overseas Territory in the South Atlantic Ocean, has a small threatened endemic flora of global conservation importance (Ashmole & Ashmole 2000, Cronk 1980, Cronk 2000, Gray *et al.* 2005, Gray *et al.* 2009), but has long been neglected in terms of scientific efforts. Perhaps this is understandable since in terms of species richness it is the poorer cousin to much richer Atlantic islands such as St Helena or the islands in Macaronesia. Occupying 97 km^2, Ascension is home to approximately twenty five native vascular plant species (Ashmole & Ashmole 2000, Cronk 2000), ten of which are considered endemic. Of these, three are considered extinct and the remaining species are under various threat categories of extinction (Table 1).

The depleted species richness of the Ascension flora may simply be a consequence of a relatively young geological age (1 million years old with the last volcanic eruption approx. 500 years ago) and isolation (1500 km from the nearest point of Africa 2300 km from South America 1300 km from St Helena). However, Ascension has been visited by few botanists, there is no systematic flora and the historic lack of taxonomic effort on Ascension (see Gray and Cavers 2014) may also be a reason why species richness is apparently low. Although Ascension is unlikely to ever reach the higher species richness of St Helena, it is likely that variation at both species and genetic levels have been overlooked. On Ascension, we suspected this to be the case for the native species *Cyperus appendiculatus* (Brongniart, 1834: 178) Kunth (1837: 81) (Cyperaceae). *Cyperus appendiculatus* is a perennial tussock-forming sedge that is considered to occur on the south Atlantic islands of Ascension, Fernando de Noronha, Martin Vas and Trinidade, and on the coast of mainland Brazil. Historically it was separated into four varieties; var. *appendiculatus*, var. *gordonii*, (Kükenthal, 1936: 436), var. *noronhae* (Ridley, 1890: 66) Kükenthal (1936: 436), and var. *atlanticus* (Hemsley, 1885: 130) Kükenthal (1936: 436). However, more recently, *C. appendiculatus* var. *gordonii* was synonymised with *C. appendiculatus, C. appendiculatus* var. *atlanticus* was recognised at species level as *C. atlanticus* Ridley and the variety *C. appendiculatus.* var. *noronhae* was retained (Govaerts *et al.* 2017) both the latter two are found only on the Brazilian islands. However, the level of taxonomic confidence across the *C. appendiculatus* group remains low since a systematic revision is currently lacking.

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To make matters more complex on Ascension there are known to be two distinct *C. appendiculatus* morphotypes, plants either displaying tall or dwarf growth forms. These morphotypes inhabit quite different environments, particularly in relation to soil type and climate. As such, we set out to determine whether these morphological differences were the result of phenotypic plasticity due to the differing environmental conditions or had a genetic basis and in effect were two different species.

TABLE 1. Endemic and one native* species from Ascension Island indicating red list status, population trends, and the major threats to survival for each species.

Species	IUCN Red List status (ver. 3.1)	Population Trend	Major Threats/Extinction cause
Anogramma ascensionis (Hook.) Diels	Critically Endangered B1ab(iii)+2ab(iii); D	Unknown	Introduced plant species
Asplenium ascensionis S.Watson	Vulnerable B1ab(iii)+2ab(iii)	Decreasing	Introduced plant species
**Cyperus appendiculatus* (Brongn.) Kunth	Least Concern	Stable	Introduced plant species
Dryopteris ascensionis (Hook.) Kuntze	Extinct		Introduced plant species
Euphorbia origanoides L.	Critically Endangered B1ab(ii,iii,iv,v)+2ab (ii,iii,iv,v)	Decreasing	Introduced plant and animal species
Oldenlandia adscensionis (DC.) Cronk	Extinct		Grazing and competition from introduced plant and animal species
Pteris adscensionis Sw.	Critically Endangered B1ac(iv)+2ac(iv)	Unknown	Grazing and competition from introduced plant and animal species
Ptisana purpurascens (de Vriese) Murdock	Critically Endangered B1ab(iii)+2ab(iii)	Unknown	Habitat loss and introduced plant species
Sporobolus caespitosus Kunth	Critically Endangered B1ab(iii)+2ab(iii)	Stable	Introduced plant species and grazing
Sporobolus durus Brongn.	Extinct		Introduced plant species and grazing
Xiphopteris ascensionensis (Hieron.) Cronk	Critically Endangered B1ab(iii)+2ab(iii)	Stable	Climate change and introduced plant species

Materials and Methods

Seed was collected from both Ascension morphotypes (Figure 1) and a common garden experiment was set up at Centre for Ecology and Hydrology in Edinburgh where plants were grown under common environmental conditions in a randomised block and subsequent morphological measurements were made. Field measurements were also made of plant height and tussock diameter where 30 individuals were randomly sampled from a 50 x 50 m area in each population, only flowering individuals were sampled and height was measured to the tallest inflorescence.

Morphometric Analysis

Here, we take plasticity to be defined as the capacity of a single genotype (population or provenance) to exhibit variable phenotypes in different environments (*sensu* Bradshaw, 1965) and, so variation in the phenotype may be expressed as:

$$VP = VG + VE + VG*E + V\text{error}$$

Where: VP = Total phenotypic variance for a trait;

VG = Genetic variance (proportion of phenotypic variation attributable to genes);

VE = Environmental variance (proportion of variation caused by the environment);

$VG*E$ = Genotype x Environment interaction (Genetic variation for phenotypic plasticity);

$Verror$ = Unexplained variance, including developmental noise, measurement error, etc.

When the plants are grown in common environment trials *VE* and *VG* **E* are minimised thus the remaining phenotypic variation is largely due to *VG*. Therefore, any population level differences that area detected can be assumed to be genetically controlled. Data were analysed using Principal Co-ordinate analysis (PCoA) and the Gower metric as data are a mix of categorical and continuous variables; differences were tested using Permanova. Two analyses were performed the first using material grown from wild collected seed in the common garden experiment. Secondly, a comparison was made between herbarium specimens from throughout the geographical range of *C. appendiculatus* group (see Table S2), undoubtedly this does not reduce phenotypic plasticity as specimens are collected *in situ*, but it helps set a potential agenda for any taxonomic revision that may be required.

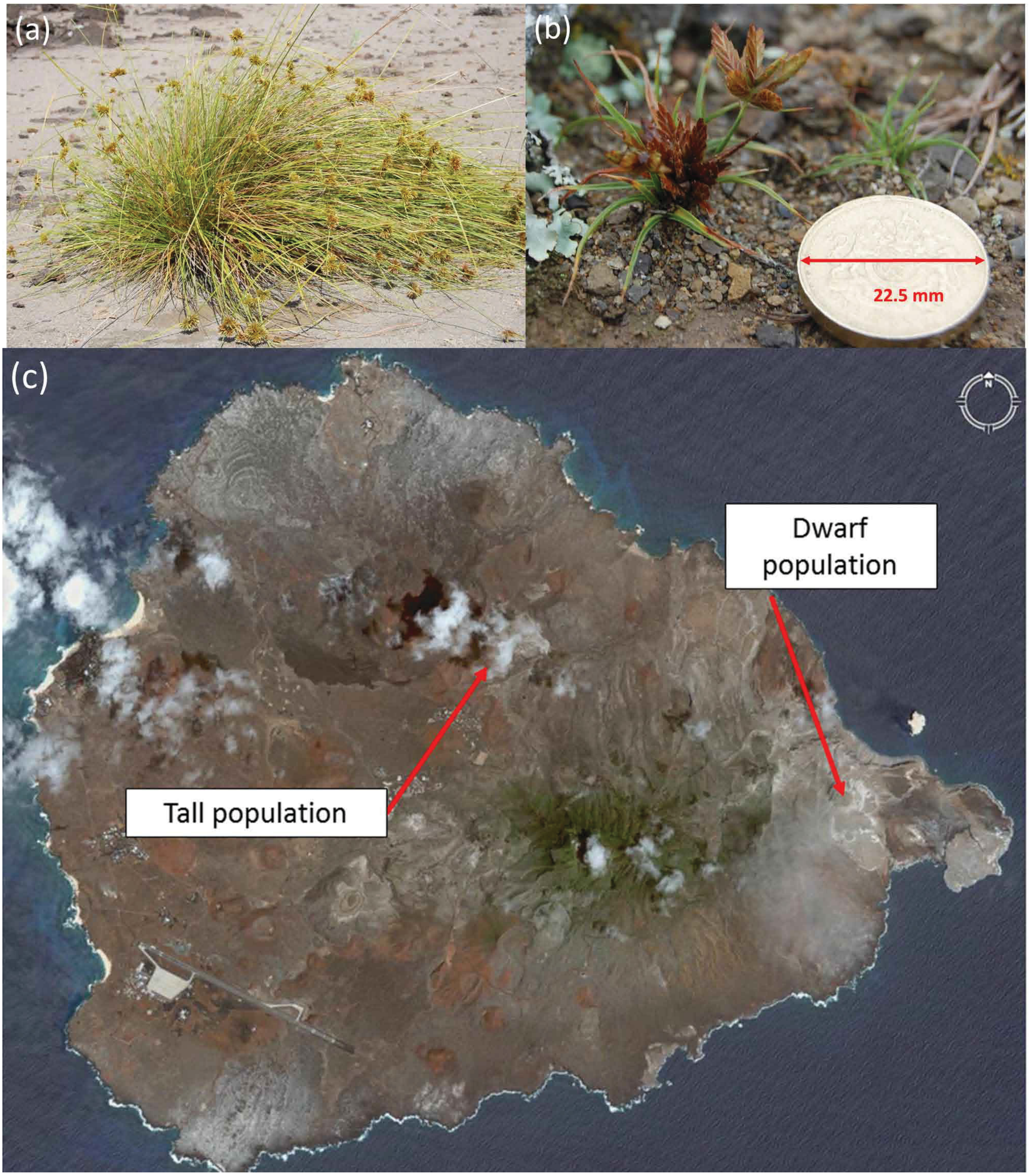

FIGURE 1. Tall (a) and dwarf (b) morphotype populations assumed to be *C. appendiculatus* (c) location of seed collection sampling from each of the two *Cyperus* populations on Ascension.

Morphometric Results

Field Measurements

Field measurements indicated that the two populations were distinct in terms of plant height and diameter both of which were correlated within populations (Table 2) corroborating previous field observations.

TABLE 2. Field measurements of plant height and diameter (cm) and strength of correlation between the two.

Population	Mean height	SE height	Mean Dia	SE Dia	Pearson's
Tall	25.8	1.31	30.0	2.25	0.61
Dwarf	3.2	0.21	3.1	0.37	0.64

Glasshouse Material

Figure 2 (a) and Table 3 shows the results of the PCoA between the two morphotypes on Ascension, Permanova analysis indicated that the differences between the two types were significant. Characters such as height, bract length, width and number, leaf length and width, stigma, anther and filament length, all have higher values in the taller plants. However, the largest glumes were found in some dwarf plants, and though the inflorescences were larger in tall plants, the number of flowers per spike were greater in some dwarf plants. Nutlets tend to be smaller in diameter in the dwarf plants but slightly more elongated.

Herbarium Specimen Comparison

Figure 2 (b) shows that across the geographic distribution of the *C. appendiculatus* group, significant pairwise differences between the island groups are found. These are stronger for the comparison between the Ascension and Brazilian plants than between plants found in the Brazilian islands alone. In the main, the Ascension plants even the tall morphotypes tend to be smaller and have a more condensed inflorescence than the Brazilian specimens. However, specimens for *C. appendiculatus* collected by H.J. Gordon from Ascension appear to have more in common with the Brazilian specimens than more recent collections from Ascension. These Gordon specimens tend to be large robust plants that have a branched or lax inflorescence (coded Ascension App in Figure 2). It is also notable that plants this large have not been collected or observed in recent collections or field work on Ascension.

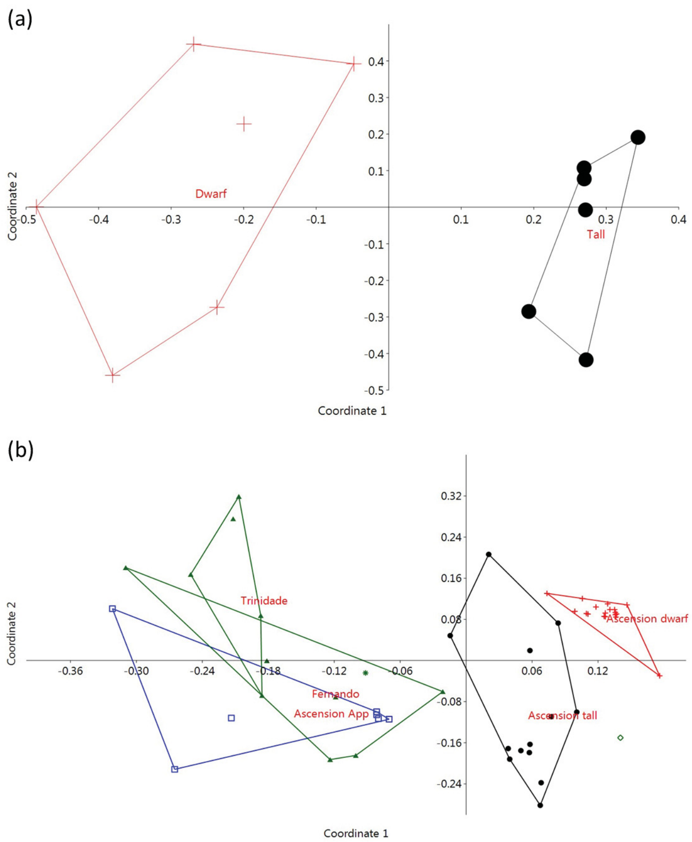

FIGURE 2. (a) Principal Co-ordinate analysis using the Gower metric of morphological variables between two morphotypes grown under common environmental conditions from seed collected from Ascension Islands. (b) Principal co-ordinate analysis of Ascension plants and herbarium specimens collected across the geographic range. Lines represent convex hulls round geographically separated populations.

The significant differences found here indicate two clear results, firstly that the dwarf plants are very distinct and are thus described as a new species, *Cyperus stroudii* below. Secondly that there does appears to be some significant separation between geographically isolated specimens. However, testing specific hypotheses about relationships across the *C. appendiculatus* group requires further examination preferably using both molecular and common garden techniques.

TABLE 3. Permanova results of pairwise differences between populations on Ascension and across the geographical range of *C. appendiculatus;* * indicates statistically significant differences.

	p-value			
Population	Ascension tall	Ascension dwarf	Ascension *C. app.*	Trinidade
Ascension dwarf	0.0021*			
Ascension App	0.0021*	0.0021*		
Trinidade	0.0168*	0.0042*	1	
Fernando	0.0021*	0.0021*	0.8064	0.4158

Taxonomy

Cyperus stroudii Gray, A. & Stott, *sp. nov*. Type:—ASCENSION ISLAND, between White Hill and Weather Post: approx. 1 km SW of Spire Beach, on flat, area composed of shallow soils derived from weathered volcanic debris, -7.944987, -14.3221200, 160 m, 21 July 2010, (Holotype: E, *A. Gray* s.n.! AG101! AG102!).

Caespitose perennial, mean height of 3.1 cm with a range of 1.6 to 9.4 cm in the type locality (n = 30), in cultivation plants achieve a greater height of up to 17 cm. Leaves, bracts, stems, and rays green to glaucous-green when fresh and glaucous when dry, papillate throughout. *Rhizome* horizontal and short up to 5 mm long. *Culms* diameter when dry 0.3–0.6 mm and 0.6–0.9 mm when fresh, trigonous but rounded, papillose and only slightly scabrous towards the inflorescence. *Leaves* In the type locality, mean leaf length is 3.2 cm with a range of 0.5 to 6.0 cm, and up to 1 mm wide, again leaves larger in cultivation 7 to 22 cm long, v-shaped, coriaceous, the margins and keel scabrid; sheaths brown. *Inflorescence* bracts leaf like 2–3, 0.6–1.7 wide and 1–13 cm long, the margins and keel scabrid, either slightly ascendant or descendant. Simple contracted ovoid inflorescence 10–20 mm diameter. Spikelets 6–10, 1–2.5 mm long, (rather finely spaced, concealing the short rachis), oblong-ellipsoid to oblong lanceolate, compressed; rachilla approximately 0.25 mm wide, successive spikes 1 mm apart; Glumes lanceolate 4 nerved when dry but appearing one nerved when fresh, pale green becoming reddish brown when ripe, persistent, 1–3 mm long, 1–2 mm wide, ovate, slightly mucronate. Stamens 3; filaments 1–3 mm long (at maturity of Nutlets); anthers (0.8–1.2) yellow. Styles and stigmas roughly equal in length 1.5, ca. 3 mm long in entirety. *Nutlet* about 0.6–2 mm long, 0.2–1 mm wide, trigonous, broadly obovoid, apex sub-acute, the base tapering from the middle, sessile, papillose, and brown. See Figures 4 and 5.

Phenology: collections were made in July and the majority of plants were in flower which appears to occur rapidly after germination and throughout the year.

Habitat: Figure 3 shows the type locality, an area of dry xeric gravel, sandy soil derived from weathered volcanic material, 300 m. There are few other native species in the area except *Aristida adscensionis* Linnaeus (1753: 82) and *Psilotum nudum* (Linnaeus 1753: 1100–1101) Palisot de Beauvois (1805: 112) and introduced plants dominate the vegetation including *Psidium guajava* Linnaeus (1753: 470), *Juniperus bermudiana* Linnaeus (1753: 1039), *Cyperus owanii* Boeckeler (1878: 29).

Distribution: endemic to the island of Ascension.

Conservation Evaluation: *Cyperus stroudii* is known only from Ascension Island from a single locality, occupying a very small area that is declining in quality due to encroachment by invasive species. Using IUCN (2012) criteria we would preliminary evaluate *C. stroudii* as Critically Endangered B2ab(iii)+2ab(iii).

Etymology: named for Stedson Stroud of St Helena who has dedicated many years to the conservation of the endemic and native plants of Ascension and St Helena. Stedson also aided in the collecting of material and his company in the field has always been a privilege.

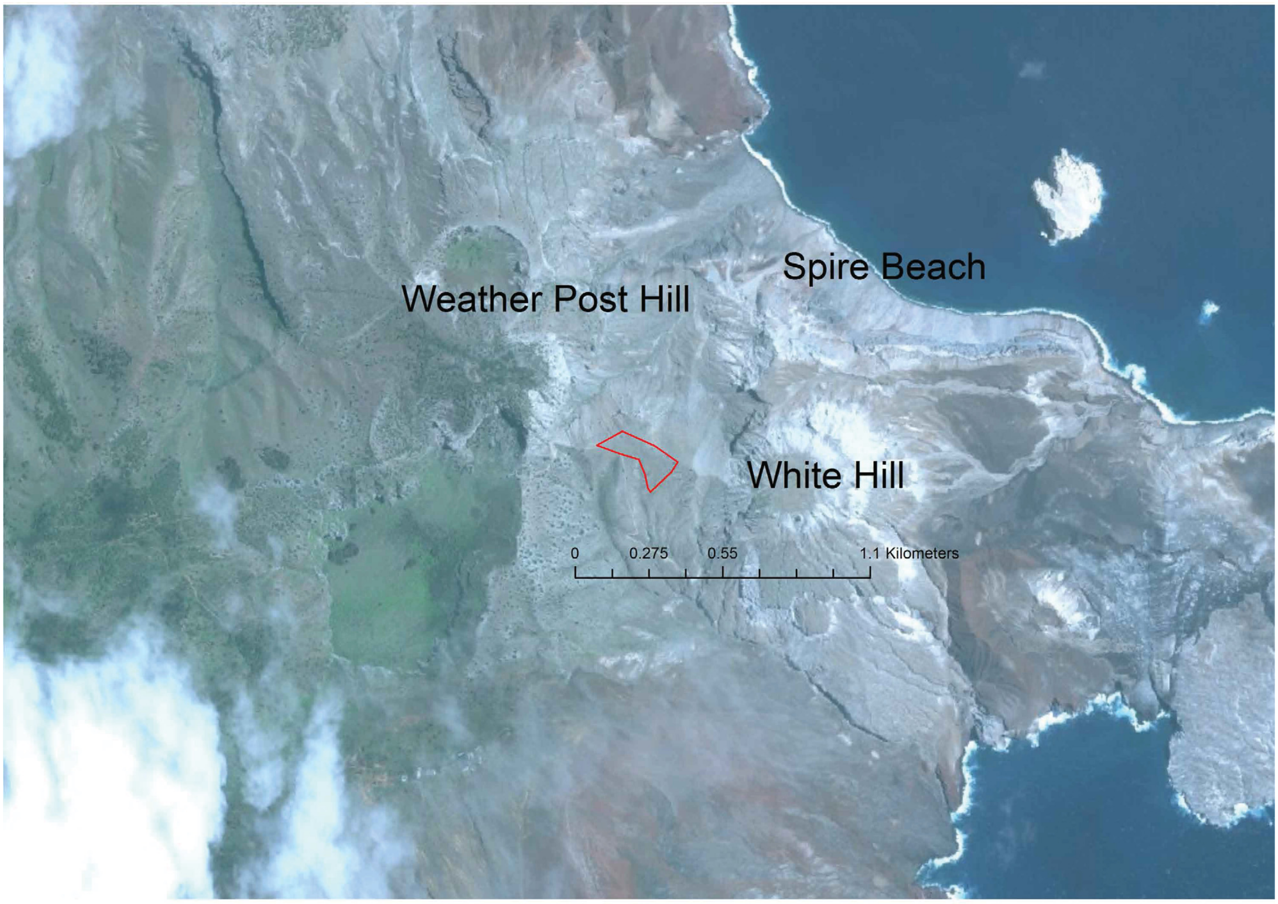

FIGURE 3. Boundary of the type locality for *Cyperus stroudii* marked in red and place names mentioned in the text.

FIGURE 4. Holotype of *Cyperus stroudii*

FIGURE 5. Close up of *Cyperus stroudii* characters (a) spikelets, glumes and nutlet (x 8 magnification red line is 6.4 mm) and (b) Nutlet(x 32 magnification yellow line is 1.6 mm).

Notes: *Cyperus stroudii* is in *Cyperus* sect. *Turgiduli* (C.B.Clarke) Kük. (Kükenthal 1935–36; Wilson 1991; Larridon *et al.* 2011). Morphologically, *Cyperus stroudii* is most similar to *C. appendiculatus* (Brongn.) Kunth, a species of the islands of the South Atlantic (Ascension, Fernando de Noronha, Trindade). These two species are sympatric on Ascension. In the type locality, *C. stroudii* can be quickly distinguished in the field because of its diminutive size, moving further afield it can be difficult to distinguish from *C. appendiculatus* because of the presence of intermediates and microscopic examination is required. The degree of any hybridisation and or environmental influence in the intermediate population has yet to be determined but should be a focus of a future revision of the entire *C. appendiculatus* group. The conservation of *C. stroudii* is also in need of some urgent action. The single population is extremely vulnerable to invasive species and stochastic events that could easily render the population extinct. A small *ex situ* collection exists in Edinburgh but we would recommend further seed collection and the establishment of on island cultivated material as well as a collection housed in the Millennium Seed Bank.

Acknowledgements

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Supplementary Material

Cyperus stroudii (CYPERACEAE), a new species from Ascension Island, South Atlantic Ocean.
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TABLE S1. Morphometric variables included in the analysis and in which situation they were examined.

Morphology	Units/Category	Glasshouse	Herbarium	Field
Anther length	mm	Y		
Basal culm leaves overlap?	Y/N	Y	Y	
Bract length	mm	Y	Y	
Bract Length	mm	Y		
Bract Width	mm	Y		
Bracts	number	Y	Y	
Bracts margins	Scabrid or not	Y	Y	
Culm	very slender/slender/robust	Y	Y	
Culm shape	trigonous or not	Y	Y	
Culm texture	smooth/channelled/deeply channelled	Y	Y	
Filament length	mm	Y		
Glume length	mm	Y		
Inflorescence	number of spikes	Y	Y	
Inflorescence Diameter	mm	Y		
Inflorescence shape	Compact/slightly spreading/loose	Y	Y	
Inflorescence width	mm	Y	Y	
Inflorescences per plant	number	Y		
Leaf Length	mm	Y		
Leaf margins	Scabrid or not	Y	Y	
Leaf width	mm	Y		
Leaves	very slender/slender/robust	Y	Y	
Longest Spikelet length	mm	Y	Y	
Nutlet Diameter	mm	Y		
Nutlet length	mm	Y		
Plant diameter	mm	Y	Y	Y
Plant height	mm	Y	Y	Y
Shortest spikelet length	mm	Y	Y	
Spike length	mm	Y	Y	
Spike Shortest Peduncle length	mm	Y	Y	
Spikelet	number of scales	Y	Y	
Spikelet position	90° to rachis (1) < 90° angle to rachis (0)	Y	Y	
Spikelet shape	linear-lanceolate/lanceolate	Y	Y	
Spikelet length	mm	Y		
Spikelets per Inflorescence	number	Y		
Spikes Longest Peduncle length	mm	Y	Y	
Spikes per spikelet	number	Y		
Spikes shape	round/oval/other	Y	Y	
Stigma length	mm	Y		

TABLE S2. specimens examined.

Collector / collection number	Species	Herbarium
Chauvin, F.J. 1369	*Cyperus dianae* Steud. (digitised specimen)	P
Chauvin, F.J. 1369	*Cyperus dianae Steud.* (digitised specimen)	P
Cuyler, W. K., no. 4120	*Cyperus appendiculatus* (Brongn.) Kunth	NY
Duffey, E. A. G., no. 133.	*Cyperus appendiculatus* (Brongn.) Kunth	K
Duffey, E. A. G., no. 293.	*Cyperus appendiculatus* (Brongn.) Kunth	K
Duffey, E. A. G., no. 303.	*Cyperus appendiculatus* (Brongn.) Kunth	K
Duffey, E. A. G., no. 333	*Cyperus appendiculatus* (Brongn.) Kunth	K
Duffey, E. A. G., no. 342	*Cyperus appendiculatus* (Brongn.) Kunth	K
D'Urville	*Cyperus appendiculatus* (Brongn.) Kunth (digitised specimen)	P
D'Urville	*Cyperus appendiculatus* (Brongn.) Kunth (digitised specimen)	P
D'Urville	*Cyperus appendiculatus* (Brongn.) Kunth (digitised specimen)	P
Gordon, H. J.	*Cyperus appendiculatus* (Brongn.) Kunth	K
Gordon, H. J.	*Cyperus appendiculatus* (Brongn.) Kunth	K
Gordon, H. J.	*Cyperus appendiculatus* (Brongn.) Kunth	K
Gordon, H. J.	*Cyperus appendiculatus* (Brongn.) Kunth	K
Gordon, H. J., no. 78	*Cyperus appendiculatus* (Brongn.) Kunth	K
Lambdon, P. W and Darlow, A.	*Cyperus appendiculatus* (Brongn.) Kunth	K
Lesson	*Cyperus appendiculatus* (Brongn.) Kunth	P
McKinnan, R. S.	*Cyperus appendiculatus* var. *atlanticus* (Hemsl.) Kük.	K
Moseley.	*Cyperus appendiculatus* var. *noronhae* (Ridl.) Kük.	BM
Collector not recorded.	*Cyperus appendiculatus* (Brongn.) Kunth	BM
Ridley, Lea & Ramage, no. 130	*Cyperus appendiculatus* var. *noronhae* (Ridl.) Kük.	BM
Ridley, Lea & Ramage, no. 130x	*Cyperus appendiculatus* var. *noronhae* (Ridl.) Kük.	BM
Ridley, Lea & Ramage, no. 134x	*Cyperus appendiculatus* var. *noronhae* (Ridl.) Kük.	BM
Ridley, Lea & Ramage, no. 134y	*Cyperus appendiculatus* var. *noronhae* (Ridl.) Kük.	BM
Ridley, Lea & Ramage, no. 134z	*Cyperus appendiculatus* var. *noronhae* (Ridl.) Kük.	BM
Simmons, G. F., no. 3467	*Cyperus appendiculatus* (Brongn.) Kunth	NY
Simmons, G. F., no. 3890	*Cyperus appendiculatus* (Brongn.) Kunth	NY
Stammwitz, P.	*Cyperus appendiculatus* (Brongn.) Kunth	BM
Xavier, L. P.	*Cyperus appendiculatus* (Brongn.) Kunth	NY

BM (Natural History Museum, London)

K (Royal Botanic Gardens, Kew)

NY (New York Botanic Garden)

P (Muséum National D'Histoire Naturelle, Paris)