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VIROLOGY DIVISION NEWS

Taxonomy update for the family *Alphasatellitidae*: new subfamily, genera, and species

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Abstract

Alphasatellites (family *Alphasatellitidae*) are circular, single-stranded DNA molecules (~1–1.4 kb) that encode a replication-associated protein and have commonly been associated with some members of the families *Geminiviridae*, *Nanoviridae*, and *Metaxyviridae* (recently established). Here, we provide a taxonomy update for the family *Alphasatellitidae* following the International Committee on Taxonomy of Viruses (ICTV) Ratification Vote held in March 2021. The taxonomic update includes the establishment of the new subfamily *Petromoalphasatellitinae*. This new subfamily includes three new genera as well as the genus *Babusatellite,* which previously belonged to the subfamily *Nanoalphasatellitinae*. Additionally, three new genera and 14 new species have been established in the subfamily *Geminialphasatellitinae,* as well as five new species in the subfamily *Nanoalphasatellitinae*.

Introduction

Alphasatellitidae is a family of replication-associated protein (Rep)-expressing circular, single-stranded DNA molecules (~1–1.4 kb) that have commonly been found in association with some members of the families *Geminiviridae* (viruses in the genera *Begomovirus* and *Mastrevirus*) [14] and *Nanoviridae* [12]. Similar molecules have also been found associated with coconut foliar decay virus [4] (family *Metaxyviridae*, genus *Cofodevirus*) [13]. Alphasatellites are unable to trans-replicate the *bona fide* genome components of these 'helper viruses' or vice versa, but they do rely on them for encapsidation, movement, and vector transmission [1].

Since the establishment of the family *Alphasatellitidae* in 2018 [1], various new alphasatellites have been identified,

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and here, we provide a taxonomic update. The update includes: (1) the establishment of a new subfamily, *Petromoalphasatellitinae*; (2) reassignment of existing family members and assignment of new members to the subfamily *Petromoalphasatellitinae*; (3) the establishment of three new genera and 14 new species in the subfamily *Geminialphasatellitinae*; and (4) the establishment of five new species in the subfamily *Nanoalphasatellitinae*.

Geminialphasatellitinae

A genus demarcation threshold of 70% and a species demarcation threshold of 88% based on genome-wide pairwise identity values were recommended by Briddon et al. [1] (Fig. 1). Accordingly, the members were classified into four genera (*Ageyesisatellite*, *Clecrusatellite*, *Colecusatellite*, and *Gosmusatellite*) and a total of 41 species. In the last couple of years, various geminialphasatellites have been identified, and using the taxonomic guidelines outlined by Briddon et al. [1], we established three new genera (*Draflysatellite*, *Somasatellite*, and *Whiflysatellite*) to accommodate the two previously unassigned species (*Dragonfly associated alphasatellite* and *Whitefly associated Guatemala alphasatellite 1*) and one new species (*Sorghum mastrevirus associated alphasatellite*). In addition to these, we established 12 new species in the genera *Clecrusatellite* ($n = 7$), *Colecusatellite* ($n = 2$), and *Gosmusatellite* ($n = 3$). The details of the new taxa are provided in Table 1. With all the new geminialphasatellites being identified, we reanalysed the distribution of pairwise identity values for 960 complete sequences with intact Rep open reading frames using SDT v1.2 [7] and determined that the 88% species demarcation threshold is still a valid criterion for their classification (Fig. 1).

Nanoalphasatellitinae

A genus demarcation threshold of 67% and a species demarcation threshold of 80% based on genome-wide pairwise identity values were recommended previously by Briddon et al. [1]. This resulted in the original creation of 19 species, which were assigned to seven genera (*Babusatellite*, *Clostunsatellite*, *Fabenesatellite*, *Milvetsatellite*, *Mivedwarsatellite*, *Sophoyesatellite*, and *Subclovsatellite*). The major change in this subfamily is the reassignment of the genus *Babusatellite* to the subfamily *Petromoalphasatellitinae*. We also established five new species in the genera *Mivedwarsatellite* ($n = 3$), *Sophoyesatellite* ($n = 1$), and *Subclovsatellite* ($n = 1$). To verify that, with the reassignment of *Babusatellite* to the subfamily *Petromoalphasatellitinae*, the species demarcation threshold of 80% is still valid, we reanalysed the distribution of pairwise identity values for 104 complete nanoalphasatellite sequences with intact Rep open reading frames using SDT v1.2 [7] and confirmed the species demarcation threshold (Fig. 1).

Petromoalphasatellitinae

In 2018, novel types of single-stranded DNA molecules comprising the genome of coconut foliar decay virus [4] (family *Metaxyviridae*) were identified. The virus was found to affect only coconut palm (*Cocos nucifera*) and is restricted to the Vanuatu Archipelago [8, 9]. Nine different alphasatellites are associated with coconut foliar decay virus. Our analysis of these alphasatellites revealed that, based on a species demarcation threshold of 81% sequence identity, they can be classified in several distinct species (Fig. 1). Applying a genus demarcation threshold of 68% sequence identity among members, three new genera, *Cocosatellite* (***Coco*** for coconut), *Coprasatellite* (***Copra*** for coconut meat), and *Kobbarisatellite* (***Kobbari*** is an Indian dish from coconut meat) were established. Five of the seven alphasatellite species were assigned to the genus *Cocosatellite*, one to the genus *Coprasatellite*, and one to the genus *Kobbarisatellite* (Table 1).

In addition to the creation of these three genera, we reassigned the genus *Babusatellite* to the new subfamily *Petromoalphasatellitinae*, as these alphasatellites collectively associate with viruses that infect perennial tropical monocotyledonous plants. Moreover, their respective size range is between those of the members of the subfamilies *Geminialphasatellitinae* and *Nanoalphasatellitinae*. Finally, phylogenetic analysis clearly supports inclusion of the species of the genus *Babusatellite* in the same subfamily along with the species of the newly established genera *Cocosatellite, Coprasatellite*, and *Kobbarisatellite* (Fig. 2). The distribution of the pairwise identity values for the 28 petromoalphasatellites is shown in Fig. 1.

Based on the phylogenetic analysis coupled with pairwise comparisons, we moved three species (*Banana bunchy top alphasatellite 2*, *Banana bunchy top alphasatellite 3*, and *Cardamom bushy dwarf alphasatellite*) from the genus *Babusatellite* to a new genus, *Muscarsatellite* (***Muscar*** from *Musa* and *Elettaria cardamomum*). A summary of the genera and species is provided in Table 1.

For the classification of new petromoalphasatellites, we recommend similar steps to those outlined by Briddon et al. [1]. To resolve conflict in cases where (1) a complete petromoalphasatellite sequence shares ≥81% pairwise identity with sequences of members of two different species or (2) a complete petromoalphasatellite sequence shares ≥81% pairwise identity with sequences of one or more members of a particular species while sharing <81% identity with the sequences of the majority of the members of that particular species:

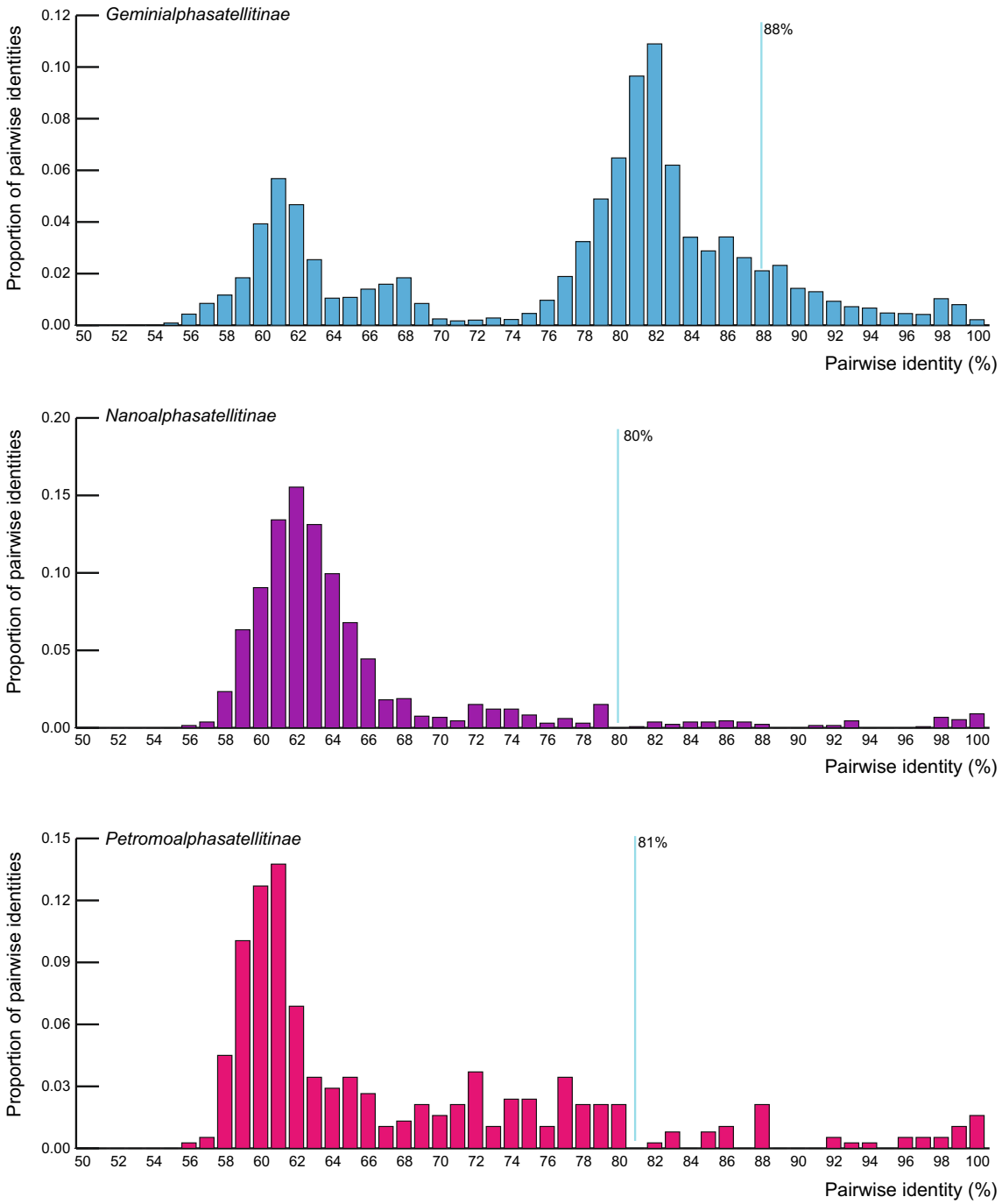


Fig. 1 Distribution of pairwise identity values of complete sequences with intact Rep ORFs of members of the subfamilies *Geminialphasatellitinae* ($n = 960$), *Nanoalphasatellitinae* ($n = 104$), and *Petromoalphasatellitinae* ($n = 28$), determined using SDT v1.2 [7]

(1) The new petromoalphasatellite should be assigned to the species whose members share with it the highest pairwise sequence identity.
(2) The petromoalphasatellite should be classified as belonging to any species in which it shares ≥81% pairwise sequence identity with any existing member of that species, even if it has <81% pairwise sequence identity to other members of that species.

Table 1 Summary of the genera and species in the subfamilies *Geminialphasatellitinae*, *Nanoalphasatellitinae*, and *Petromoalphasatellitinae*

Subfamily	Genus		Species	Alphasatellite name	Isolate	Accession no.
Geminialphasatellitinae	*Ageyesisatellite*		*Ageratum yellow vein Singapore alphasatellite*	ageratum yellow vein Singapore alphasatellite	SG-98	AJ416153
			Cotton leaf curl Saudi Arabia alphasatellite	cotton leaf curl Saudi Arabia alphasatellite	SA-Jazan-13	HG530543
	Clecrusatellite	◊	*Ash gourd yellow vein mosaic alphasatellite*	ash gourd yellow vein mosaic alphasatellite	IN-UdA-15	KX363561
		◊	*Capsicum India alphasatellite*	begomovirus-associated alphasatellite sp.	IN-PJ-Cap-15	KU923759
		◊	*Chiapas weed alphasatellite*	begomovirus-associated alphasatellite	MX-UHAsV-1-CD-W-2014	MN203219
			Cleome leaf crumple alphasatellite	cleome leaf crumple alphasatellite	BR-Mato Grosso do Sul-07	FN436007
			Croton yellow vein mosaic alphasatellite	croton yellow vein mosaic alphasatellite	IN-Haryana-Acalypha-07	FN658711
			Euphorbia yellow mosaic alphasatellite	euphorbia yellow mosaic alphasatellite	BR-Mato grosso do sul-1-07	FN436008
			Melon chlorotic mosaic alphasatellite	melon chlorotic mosaic alphasatellite	VE-2009_02_04_0-09	HM163578
			Sida Cuba alphasatellite	sida Cuba alphasatellite	CU-Trinidad-07	HE806451
		◊	*Tomato leaf curl Anand alphasatellite*	tomato leaf curl Anand alphasatellite	IN-Anand-2016	MH577036
		◊	*Tomato leaf curl New Delhi alphasatellite*	tomato leaf curl New Delhi alphasatellite	IN-VNS_SP4-Luf-15	MH550542
		◊	*Tomato leaf curl Virudhunagar alphasatellite*	tomato leaf curl Virudhunagar alphasatellite	IN-sev-Mom-16	KY848691
			Tomato yellow spot alphasatellite	tomato yellow spot alphasatellite	BR-Dou1095.1-11	KX348228
		◊	*Tomato yellow spot alphasatellite 2*	tomato yellow spot alphasatellite 2	AR-Jujuy-Yuto-Leonurus417-2008	MN518743
			Whitefly associated Guatemala alphasatellite 2	whitefly associated Puerto Rico alphasatellite 2	GT-GtTo2-1-10	KT099170
			Whitefly associated Puerto Rico alphasatellite 1	whitefly associated Puerto Rico alphasatellite 1	PR-PR3-6-10	KT099173
	Colecusatellite		*Ageratum enation alphasatellite*	ageratum enation alphasatellite	IN-Luc-12	JX913532
			Ageratum yellow vein alphasatellite	ageratum yellow vein alphasatellite	SG-98	AJ238493
			Ageratum yellow vein China alphasatellite	ageratum yellow vein China alphasatellite	PH-Davao-SN3-Synedrella nodiflora-12	KF785752
			Ageratum yellow vein India alphasatellite	ageratum yellow vein India alphasatellite	IN-Luc-parthenium-12	JX570736
			Bhendi yellow vein alphasatellite	bhendi yellow vein alphasatellite	IN-Har-07	FN658716

Table 1 (continued)

Subfamily	Genus		Species	Alphasatellite name	Isolate	Accession no.
			Cassava mosaic Madagascar alphasatellite	cassava mosaic Madagascar alphasatellite	MG-Diana-635A1-11	HE984148
			Chilli leaf curl alphasatellite	chilli leaf curl alphasatellite	IN-273-06	KF471043
			Cotton leaf curl Egypt alphasatellite	cotton leaf curl Egypt alphasatellite	EG-SB45-95	AJ512960
			Cotton leaf curl Gezira alphasatellite	cotton leaf curl Gezira alphasatellite	ML-Bamako-okra-06	EU589450
			Cotton leaf curl Lucknow alphasatellite	cotton leaf curl Lucknow alphasatellite	IN-Luc-10	HQ343234
			Cotton leaf curl Multan alphasatellite	cotton leaf curl Multan colecusatellite	PK-Fai01-98	AJ132344
			Gossypium darwinii symptomless alphasatellite	Gossypium darwinii symptomless alphasatellite	PK-Mul-Dav7C-06	EU384623
			Malvastrum yellow mosaic alphasatellite	malvastrum yellow mosaic alphasatellite	CN-Hn39	AM236765
			Malvastrum yellow mosaic Cameroon alphasatellite	malvastrum yellow mosaic Cameroon satellite	CM-Mundemba-UMU1D1-08	FN675297
			Pedilanthus leaf curl alphasatellite	pedilanthus leaf curl alphasatellite	IN-carrot	KX168428
			Sida leaf curl alphasatellite	sida leaf curl alphasatellite	PK-Lahore-Alcea rosea-06	FR772088
		◊	*Sida leaf curl alphasatellite 2*	sida leaf curl alphasatellite	IN-Gandhinagar-Sida-2016	KX513861
			Sida yellow vein Vietnam alphasatellite	sida yellow vein Vietnam alphasatellite	VN-Han-05	DQ641718
			Sunflower leaf curl Karnataka alphasatellite	sunflower leaf curl Karnataka alphasatellite	IN-tomato-11	JX569789
			Synedrella leaf curl alphasatellite	synedrella leaf curl alphasatellite	IN-Por-synf_1-09	KJ939346
			Tobacco curly shoot alphasatellite	tobacco curly shoot alphasatellite	IN-WSF1-Helianthus-10	HQ407396
			Tomato leaf curl Buea alphasatellite	tomato leaf curl Buea alphasatellite	CM-Buea-TOS2D1-07	FN675299
			Tomato leaf curl Cameroon alphasatellite	tomato leaf curl Cameroon alphasatellite	CM-Buea-OMHD3-08	FN675296
		◊	*Tomato leaf curl Pakistan alphasatellite*	tomato leaf curl alphasatellite	PK-SZ_258-Gos-15	KY420167
			Tomato yellow leaf curl China alphasatellite	tomato yellow leaf curl China alphasatellite	PK-Fai-09	AM749493
			Tomato yellow leaf curl Thailand alphasatellite	tomato yellow leaf curl Thailand alphasatellite	TH-Y70-03	AJ579359
			Tomato yellow leaf curl Yunnan alphasatellite	tomato yellow leaf curl Yunnan alphasatellite	CN-YN4368_69-14	KX759649

Table 1 (continued)

Subfamily		Genus		Species	Alphasatellite name	Isolate	Accession no.
	▶	*Draflysatellite*	◊	*Dragonfly associated alphasatellite*	dragonfly associated alphasatellite	PR-09	JX458742
		Gosmusatellite	◊	*Cotton leaf curl Cameroon alphasatellite*	cotton leaf curl Gezira alphasatellite 3	CM-OBKG-Okra-2007	MN614472
			◊	*Eclipta yellow vein alphasatellite*	eclipta yellow vein alphasatellite	PK-AlYVA-S3-13	KX938425
				Gossypium mustelinum symptomless alphasatellite	Gossypium mustelinum symptomless alphasatellite	PK-Mul-2-06	EU384656
				Hollyhock yellow vein alphasatellite	hollyhock yellow vein alphasatellite	PK-Lahor-17_5-06	FR772086
				Mesta yellow vein mosaic alphasatellite	mesta yellow vein mosaic alphasatellite	IN-Ludhiana-Okra-10	JX183090
				Okra enation leaf curl alphasatellite	okra enation leaf curl alphasatellite	IN-Surat-11	HF546575
				Okra yellow crinkle Cameroon alphasatellite	okra yellow crinkle Cameroon alphasatellite	CM-Lys1sp3-08	FN675285
				Vernonia yellow vein Fujian alphasatellite	vernonia yellow vein Fujian alphasatellite	IN-Vamban-black-gram-12	KC959931
	▶	*Somasatellite*	◊	*Sorghum mastrevirus associated alphasatellite*	sorghum mastrevirus associated alphasatellite	RE-Bassin plat-Sorghum arundinaceum-RE180_a-2017	MN901968
	▶	*Whiflysatellite*	◊	*Whitefly associated Guatemala alphasatellite 1*	whitefly associated Guatemala alphasatellite 1	WfaGA-[GT-GtTo2_2-12]	KT099172
Nanoalphasatellitinae		*Clostunsatellite*		*Milk vetch dwarf alphasatellite 2*	milk vetch dwarf alphasatellite 2	MVDC3A-JR-C3-96	AB000922
				Pea necrotic yellow dwarf alphasatellite 2	pea necrotic yellow dwarf alphasatellite 2	PNYD3A-AT-Gross_Enzersdorf_1-10	KC979052
				Sophora yellow stunt alphasatellite 4	sophora yellow stunt alphasatellite 4	SYS9A-IR-Kerman-Ta1-14	KX534409
				Sophora yellow stunt alphasatellite 5	sophora yellow stunt alphasatellite 5	SYS8A-IR-Kerman-Ta1-14	KX534398
				Subterranean clover stunt alphasatellite 2	subterranean clover stunt alphasatellite 2	SCSC6A-[AU-C6-93]	U16735
		Fabenesatellite		*Faba bean necrotic yellows alphasatellite 2*	faba bean necrotic yellows alphasatellite 2	FBNYC9A-SY-C9-93	AJ005966
		Milvetsatellite		*Milk vetch dwarf alphasatellite 3*	milk vetch dwarf alphasatellite 3	MVDC10A-JR-C10-97	AB009047
		Mivedwarsatellite		*Faba bean necrotic stunt alphasatellite*	faba bean necrotic stunt alphasatellite	AZ-12b-10	KC978990
				Milk vetch dwarf alphasatellite 1	milk vetch dwarf alphasatellite 1	MVDC1A-JR-C1-96	AB000920
			◊	*Milk vetch dwarf China alphasatellite*	milk vetch dwarf C1 alphasatellite	CN-G48-2017	MN059431
			◊	*Parsley severe stunt alphasatellite 3*	parsley severe stunt alphasatellite 3	DE-Pa21-2017	MK039141

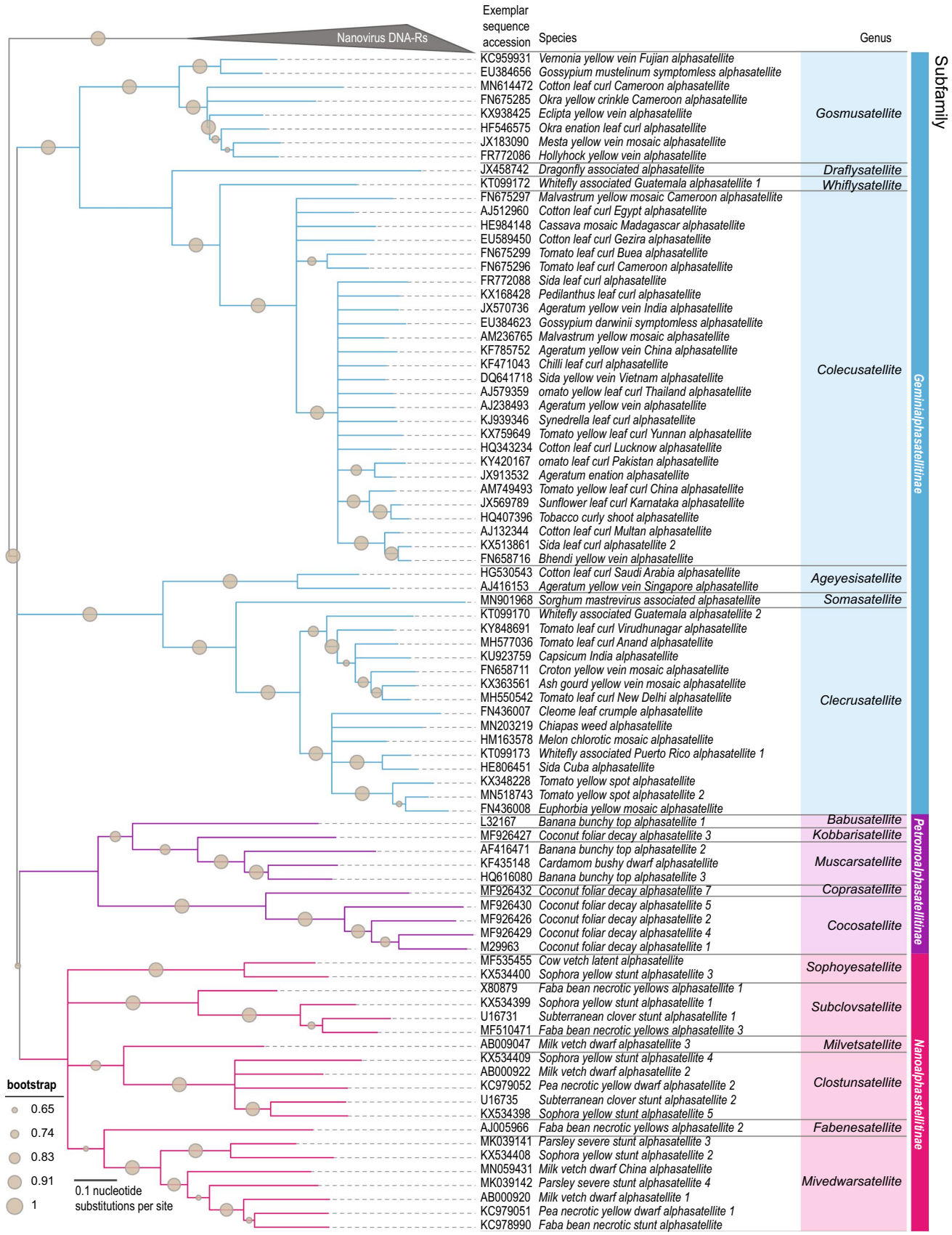
Table 1 (continued)

Subfamily	Genus		Species	Alphasatellite name	Isolate	Accession no.
		◊	*Parsley severe stunt alphasatellite 4*	parsley severe stunt alphasatellite 4	DE-Pa21-2017	MK039142
			Pea necrotic yellow dwarf alphasatellite 1	pea necrotic yellow dwarf alphasatellite 1	PNYD1A-AT-Gross_Enzersdorf_1-10	KC979051
			Sophora yellow stunt alphasatellite 2	sophora yellow stunt alphasatellite 2	SYS4A-IR-Kerman-Ta1-14	KX534408
	Sophoyesatellite	◊	*Cow vetch latent alphasatellite*	cow vetch latent virus alphasatellite	FR-VcLV_Sambuc-10	MF535455
			Sophora yellow stunt alphasatellite 3	sophora yellow stunt alphasatellite 3	SYS7A-IR-Kerman-Ta1-14	KX534400
	Subclovsatellite		*Faba bean necrotic yellows alphasatellite 1*	faba bean necrotic yellows alphasatellite 1	FBNYC1A-SY-C1-88	X80879
		◊	*Faba bean necrotic yellows alphasatellite 3*	faba bean necrotic yellows virus associated alphasatellite 1	TN-Tuf9_1-15	MF510471
			Sophora yellow stunt alphasatellite 1	sophora yellow stunt alphasatellite 1	SYSA1-[IR-Kerman-Ta1-14]	KX534399
			Subterranean clover stunt alphasatellite 1	subterranean clover stunt alphasatellite 1	SCSC2A-AU-C2-93	U16731
● *Petromoalphasatellitinae*	*Babusatellite*		*Banana bunchy top alphasatellite 1*	banana bunchy top alphasatellite 1	BBTS2A-93	L32167
	► *Cocosatellite*	◊	*Coconut foliar decay alphasatellite 1*	coconut foliar decay alphasatellite 1	VU-85	M29963
		◊	*Coconut foliar decay alphasatellite 2*	coconut foliar decay alphasatellite 2	VU-89	MF926426
		◊	*Coconut foliar decay alphasatellite 4*	coconut foliar decay alphasatellite 4	VU-89	MF926429
		◊	*Coconut foliar decay alphasatellite 5*	coconut foliar decay alphasatellite 5	VU-89	MF926430
	► *Coprasatellite*	◊	*Coconut foliar decay alphasatellite 7*	coconut foliar decay alphasatellite 7	VU-89	MF926432
	► *Kobbarisatellite*	◊	*Coconut foliar decay alphasatellite 3*	coconut foliar decay alphasatellite 3	VU-89	MF926427
	► *Muscarsatellite*	◊	*Banana bunchy top alphasatellite 2*	banana bunchy top alphasatellite 2	BBTS3A-VN-VB-sat3-00	AF416471
		◊	*Banana bunchy top alphasatellite 3*	banana bunchy top alphasatellite 3	BBTHA-CN-Haikou-10	HQ616080
		◊	*Cardamom bushy dwarf alphasatellite*	cardamom bushy dwarf alphasatellite	IN-Kalimpong-07	KF435148

The symbol "●" indicates a new subfamily, the symbol "►" indicates a new genus, and the symbol "◊" indicates a new species

Concluding remarks

As more sequence data become available, more changes to *Alphasatellitidae* taxonomy will certainly occur. We would also like to inform the *Alphasatellitidae* research community that a standardized binomial species nomenclature, consisting of the genus name and a free-form species epithet, has been ratified by the International Committee on Taxonomy of Viruses (ICTV) [10]. This needs to be adopted for currently established species in the family *Alphasatellitidae* by the year 2023. Thus, we encourage the community to engage with the ICTV *Geminiviridae* and *Tolecusatellitidae* Study Group and the *Nanoviridae* Study Group to determine the binomial names for current and new species in the family *Alphasatellitidae*.


Nanovirus DNA-Rs
Exemplar sequence accession
Species
Genus
Subfamily
KC959931 Vernonia yellow vein Fujian alphasatellite
EU384656 Gossypium mustelinum symptomless alphasatellite
MN614472 Cotton leaf curl Cameroon alphasatellite
FN675285 Okra yellow crinkle Cameroon alphasatellite
KX938425 Eclipta yellow vein alphasatellite
HF546575 Okra enation leaf curl alphasatellite
JX183090 Mesta yellow vein mosaic alphasatellite
FR772086 Hollyhock yellow vein alphasatellite
Gosmusatellite
JX458742 Dragonfly associated alphasatellite
Draflysatellite
KT099172 Whitefly associated Guatemala alphasatellite 1
Whiflysatellite
FN675297 Malvastrum yellow mosaic Cameroon alphasatellite
AJ512960 Cotton leaf curl Egypt alphasatellite
HE984148 Cassava mosaic Madagascar alphasatellite
EU589450 Cotton leaf curl Gezira alphasatellite
FN675299 Tomato leaf curl Buea alphasatellite
FN675296 Tomato leaf curl Cameroon alphasatellite
FR772088 Sida leaf curl alphasatellite
KX168428 Pedilanthus leaf curl alphasatellite
JX570736 Ageratum yellow vein India alphasatellite
EU384623 Gossypium darwinii symptomless alphasatellite
AM236765 Malvastrum yellow mosaic alphasatellite
KF785752 Ageratum yellow vein China alphasatellite
KF471043 Chilli leaf curl alphasatellite
DQ641718 Sida yellow vein Vietnam alphasatellite
AJ579359 omato yellow leaf curl Thailand alphasatellite
AJ238493 Ageratum yellow vein alphasatellite
KJ939346 Synedrella leaf curl alphasatellite
KX759649 Tomato yellow leaf curl Yunnan alphasatellite
HQ343234 Cotton leaf curl Lucknow alphasatellite
KY420167 omato leaf curl Pakistan alphasatellite
JX913532 Ageratum enation alphasatellite
AM749493 Tomato yellow leaf curl China alphasatellite
JX569789 Sunflower leaf curl Karnataka alphasatellite
HQ407396 Tobacco curly shoot alphasatellite
AJ132344 Cotton leaf curl Multan alphasatellite
KX513861 Sida leaf curl alphasatellite 2
FN658716 Bhendi yellow vein alphasatellite
Colecusatellite
HG530543 Cotton leaf curl Saudi Arabia alphasatellite
AJ416153 Ageratum yellow vein Singapore alphasatellite
Ageyesisatellite
MN901968 Sorghum mastrevirus associated alphasatellite
Somasatellite
KT099170 Whitefly associated Guatemala alphasatellite 2
KY848691 Tomato leaf curl Virudhunagar alphasatellite
MH577036 Tomato leaf curl Anand alphasatellite
KU923759 Capsicum India alphasatellite
FN658711 Croton yellow vein mosaic alphasatellite
KX363561 Ash gourd yellow vein mosaic alphasatellite
MH550542 Tomato leaf curl New Delhi alphasatellite
FN436007 Cleome leaf crumple alphasatellite
MN203219 Chiapas weed alphasatellite
HM163578 Melon chlorotic mosaic alphasatellite
KT099173 Whitefly associated Puerto Rico alphasatellite 1
HE806451 Sida Cuba alphasatellite
KX348228 Tomato yellow spot alphasatellite
MN518743 Tomato yellow spot alphasatellite 2
FN436008 Euphorbia yellow mosaic alphasatellite
Clecrusatellite
Geminialphasatellitinae
L32167 Banana bunchy top alphasatellite 1
Babusatellite
MF926427 Coconut foliar decay alphasatellite 3
Kobbarisatellite
AF416471 Banana bunchy top alphasatellite 2
KF435148 Cardamom bushy dwarf alphasatellite
HQ616080 Banana bunchy top alphasatellite 3
Muscarsatellite
MF926432 Coconut foliar decay alphasatellite 7
Coprasatellite
MF926430 Coconut foliar decay alphasatellite 5
MF926426 Coconut foliar decay alphasatellite 2
MF926429 Coconut foliar decay alphasatellite 4
M29963 Coconut foliar decay alphasatellite 1
Cocosatellite
Petromoalphasatellitinae
MF535455 Cow vetch latent alphasatellite
KX534400 Sophora yellow stunt alphasatellite 3
Sophoyesatellite
X80879 Faba bean necrotic yellows alphasatellite 1
KX534399 Sophora yellow stunt alphasatellite 1
U16731 Subterranean clover stunt alphasatellite 1
MF510471 Faba bean necrotic yellows alphasatellite 3
Subclovsatellite
AB009047 Milk vetch dwarf alphasatellite 3
Milvetsatellite
KX534409 Sophora yellow stunt alphasatellite 4
AB000922 Milk vetch dwarf alphasatellite 2
KC979052 Pea necrotic yellow dwarf alphasatellite 2
U16735 Subterranean clover stunt alphasatellite 2
KX534398 Sophora yellow stunt alphasatellite 5
Clostunsatellite
AJ005966 Faba bean necrotic yellows alphasatellite 2
Fabenesatellite
MK039141 Parsley severe stunt alphasatellite 3
KX534408 Sophora yellow stunt alphasatellite 2
MN059431 Milk vetch dwarf China alphasatellite
MK039142 Parsley severe stunt alphasatellite 4
AB000920 Milk vetch dwarf alphasatellite 1
KC979051 Pea necrotic yellow dwarf alphasatellite 1
KC978990 Faba bean necrotic stunt alphasatellite
Mivedwarsatellite
Nanoalphasatellitinae
bootstrap
0.65
0.74
0.83
0.91
1
0.1 nucleotide substitutions per site

◂**Fig. 2** Maximum-likelihood phylogenetic tree constructed from a MUSCLE [3] sequence alignment of representative alphasatellites using PHYML [5] with the GTR+I+G4 nucleotide substitution model (determined to be the best-fitting model by jModelTest [2]). The tree shows support for the proposed establishment of the new subfamily *Petromoalphasatellitinae* as well as support for the reassignment of the viruses in the genus *Babuvirus*. Branches with less than 60% bootstrap support have been collapsed using TreeGraph2 [11]. The tree was visualized in iToL v6 [6].

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Declarations

Conflict of interest The authors declare no conflicts of interest.

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