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The genomes of several plant species contain endogenous geminiviral sequences

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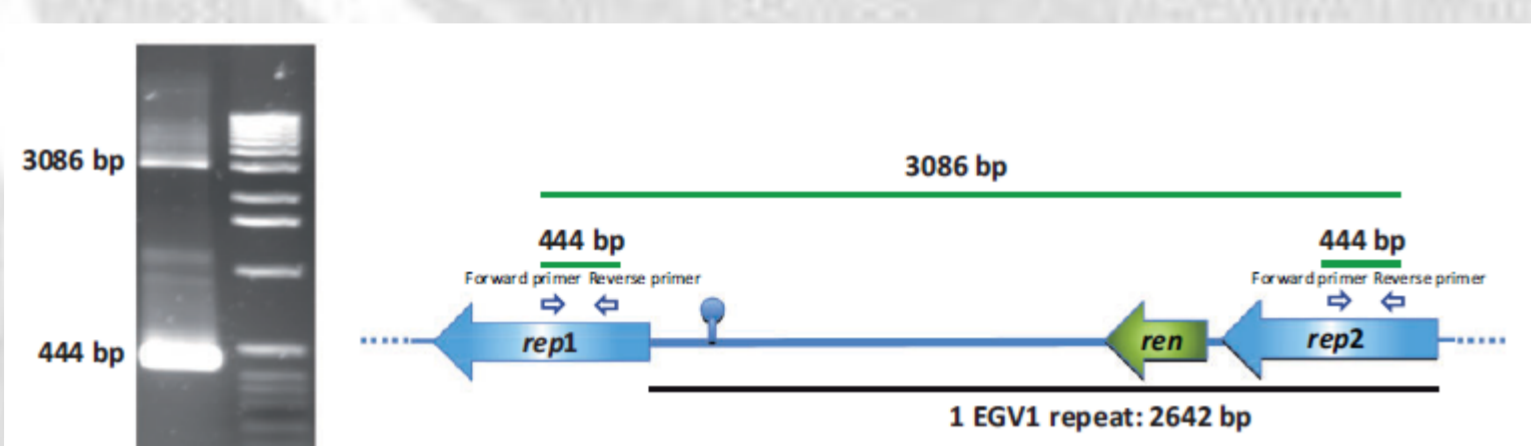
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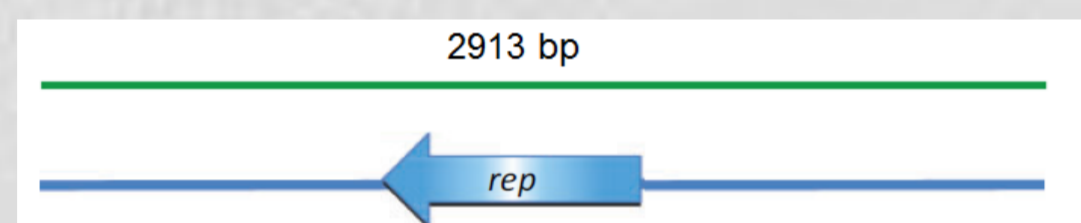
Endogenous viral sequences are essentially 'fossil records' that can sometimes reveal the genomic features of long extinct virus species. Although numerous known instances exist of single-stranded DNA (ssDNA) genomes becoming stably integrated within the genomes of bacteria and animals, there remain very few examples of such integration events in plants. The best studied of these events are those which yielded the geminivirus-related DNA elements (GRD) and the geminivirus-like elements (EGV) found respectively within the nuclear genomes of several *Nicotiana* species (Kenton *et al.* 1995; Bejarano *et al.* 1996; Ashby *et al.* 1997; Murad *et al.* 2004) and various *Dioscorea* spp. of the *Enantiophyllum* clade (Filloux *et al.*, 2015).

Those two new classes of endogenous plant virus sequence are apparently derived from ancient geminiviruses in the genus *Begomovirus*. GRD and EGV sequences likely became integrated millions years ago. Interestingly, we found evidence of natural selection actively favouring the maintenance of EGV-expressed replication-associated protein (Rep) amino acid sequences, which clearly indicates that functional EGV Rep proteins were probably expressed for prolonged periods following endogenization.

The genomes of many yam (*Dioscorea* spp.) species contain transcriptionally active endogenous geminiviral sequences that may be functionally expressed



Characteristics of the EGV1 sequence: partial tandem repeat, TAATATTAC, *rep*, *ren* and absence of *cp*



Characteristics of the EGV2 sequence: only *rep* (absence of *cp*, *ren* and *rep*)

Table 1. PCR detection of EGV1 and EGV2 sequences in the genomes of a collection of yam species.

Species	No.	Section	Clade	Country	Origin of the species	EGV1 sequence	EGV2 sequence
<i>D. alata</i> Hook.f.	14472	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	-
<i>D. eschscholzii</i> Prain & Burkill	15674	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	-
<i>D. spirocarpa</i> Prain & Burkill	15671	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	-
<i>D. alata</i> L.	213	Enantiophyllum	Enantiophyllum	India	South East Asia	+	-
<i>D. pterinifolia</i> Prain & Burkill*	271	Enantiophyllum	Enantiophyllum	Vietnam	South East Asia	+	+
<i>D. rotundata</i> Lam.	296	Enantiophyllum	Enantiophyllum	Vietnam	South East Asia	+	+
<i>D. transiensis</i> L.f.	336	Enantiophyllum	Enantiophyllum	Vietnam	South East Asia	+	+
<i>D. glabra</i> Hook.f.	21051	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	+
<i>D. coccinea</i> Prain & Burkill	6225	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	+
<i>D. hamiltonii</i> Hook.f.	6310	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	+
<i>D. heterophylla</i> Prain & Burkill	14575	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	+
<i>D. spicata</i> Thunb.	265	Enantiophyllum	Enantiophyllum	France	China	+	+
<i>D. angustata</i> Hook.f.	6482	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	+
<i>D. orbata</i> Leav.	15472	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	+
<i>D. lanceolata</i>	6282	Enantiophyllum	Enantiophyllum	Socotra	Arabian Peninsula	+	+
<i>D. alayensis</i> Hochst. ex Kunth	359	Enantiophyllum	Enantiophyllum	Benin	West Africa	+	+
<i>D. eschscholzii</i> Prain & Burkill	1	Enantiophyllum	Enantiophyllum	India	West Africa	+	+
<i>D. praefoliata</i> Benth.	255	Enantiophyllum	Enantiophyllum	Benin	West Africa	+	+
<i>D. rotundata</i> Lam.	389	Enantiophyllum	Enantiophyllum	Benin	West Africa	+	+
<i>D. alayensis</i> Hochst. ex Kunth	21944	Enantiophyllum	Enantiophyllum	Malawi	East Africa	+	+
<i>D. alayensis</i> Hochst. ex Kunth	22295	Enantiophyllum	Enantiophyllum	Malawi	East Africa	+	+
<i>D. rotundata</i> Lam.	114	Enantiophyllum	Enantiophyllum	Guinea	West Africa	+	+
<i>D. rotundata</i> Lam.	47	Enantiophyllum	Enantiophyllum	Malagasy	West Africa	+	+
<i>D. rotundata</i> Lam.	191038	Enantiophyllum	Enantiophyllum	Papua New Guinea	West Africa	+	+
<i>D. rotundata</i> Lam.	14348	Enantiophyllum	Enantiophyllum	Burkina Faso	West Africa	+	+
<i>D. rotundata</i> Lam.	159108	Enantiophyllum	Enantiophyllum	Madagascar	Madagascar	+	+
<i>D. rotundata</i> Lam.	15677	Enantiophyllum	Enantiophyllum	Benin	West Africa	+	+
<i>D. rotundata</i> Lam.	15677	Enantiophyllum	Enantiophyllum	Thailand	South East Asia	+	+
<i>D. rotundata</i> Lam.	15677	Enantiophyllum	Enantiophyllum	Madagascar	Madagascar	+	+
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