

Cauliflower gene in sugarcane?

The genes determining the fate of lateral meristem initiated at the inflorescence meristem as floral meristem in plants include CAULIFLOWER (*CAL*), APETALA 1 (*API*) and LEAFY (*LFY*). The predominant effects of the *LFY* or *API* locus are the conversion of lateral structures that develop from flower to inflorescence branches or intermediate structures with characteristics of both flowers and branches¹. In *Arabidopsis*, double mutations of *CAL* and *API* genes cause the cauliflower phenotype^{2,3}. When *apl* mutation is combined with *cal*, cells that would normally constitute a floral meristem behave as an inflorescence meristem, giving rise to additional meristems in a spiral phyllotaxy. The resulting cauliflower phenotype has an extensive proliferation of meristems at each position¹.

The molecular basis for the inflorescence structure in cauliflower (*Brassica oleracea* var. *botrytis*) is similar to the cauliflower phenotype in *Arabidopsis*. The cauliflower phenotype (curd) is due to lack of a functional *CAL* gene product^{4,5}. The flower meristem identity gene *CAL* is closely related to *API*. Even though *cal* mutant plants are phenotypically wild type, it enhances the phenotype of *apl* mutants resulting in the cauliflower phenotype. Genes involved in controlling the formation of 'curd' in cauliflower and 'leaf head' in cabbage include not only the meristem identity genes such as *LFY*, *API* and *CAL*, but also the genes controlling internode elongation and lateral meristem number, which are not yet known. Mutant *CAL* alleles are associated with an increase in the number of axillary inflorescences¹.

Cauliflower phenotype produces an arrested development stage between the vegetative and floral differentiation, i.e. the characteristic edible white curd². Curd formation in cauliflower is the natural event of morphological transformation from vegetative to arrested reproductive growth. Cauliflower upon breaking arrest produces typical cruciform flowers which do not display any homeotic transformation as in the double mutants of *Arabidopsis cal* and *apl*.

The genus *Saccharum* L. (Gramineae) consists of six species *S. officinarum* L., *S. sinense* Roxb., *S. barberi* Jesw., *S. edule* Hassk., *S. robustum* Brandes and Jesw. ex Grassl and *S. spontaneum* L., of which

the former four species are cultivated and the latter two species are wild⁶. The present day commercial sugarcane varieties are derivatives of man-made interspecific hybrids between *S. officinarum* and *S. spontaneum*, with a limited contribution from *S. barberi*, *S. sinense* and *S. robustum*. The *S. officinarum*, which is known as the noble cane, was the tropical sugarcane with soft rind, high sucrose and low fibre, much acclaimed as chewing canes and was under cultivation for sugar before the man-made hybrids. In northern India and part of China the *S. barberi* and *S. sinense* clones were cultivated for

centuries for sweeteners. These are thin canes with less sugar compared to that of *S. officinarum*. The other cultivated species *S. edule* is grown in Fiji, New Guinea, Indonesia and Malaysia by the indigenous people for its swollen and aborted inflorescence, which is edible and its cane is not sweet^{7,8}. Irvine⁹, based on taxonomic and evolutionary studies argued that in *Saccharum* there can be only two species *S. spontaneum* L. with basic chromosome number 8 and *S. officinarum* L. with basic chromosome number 10, and *S. barberi*, *S. sinense*, *S. robustum* and *S. edule* will come under *S. officinarum*.

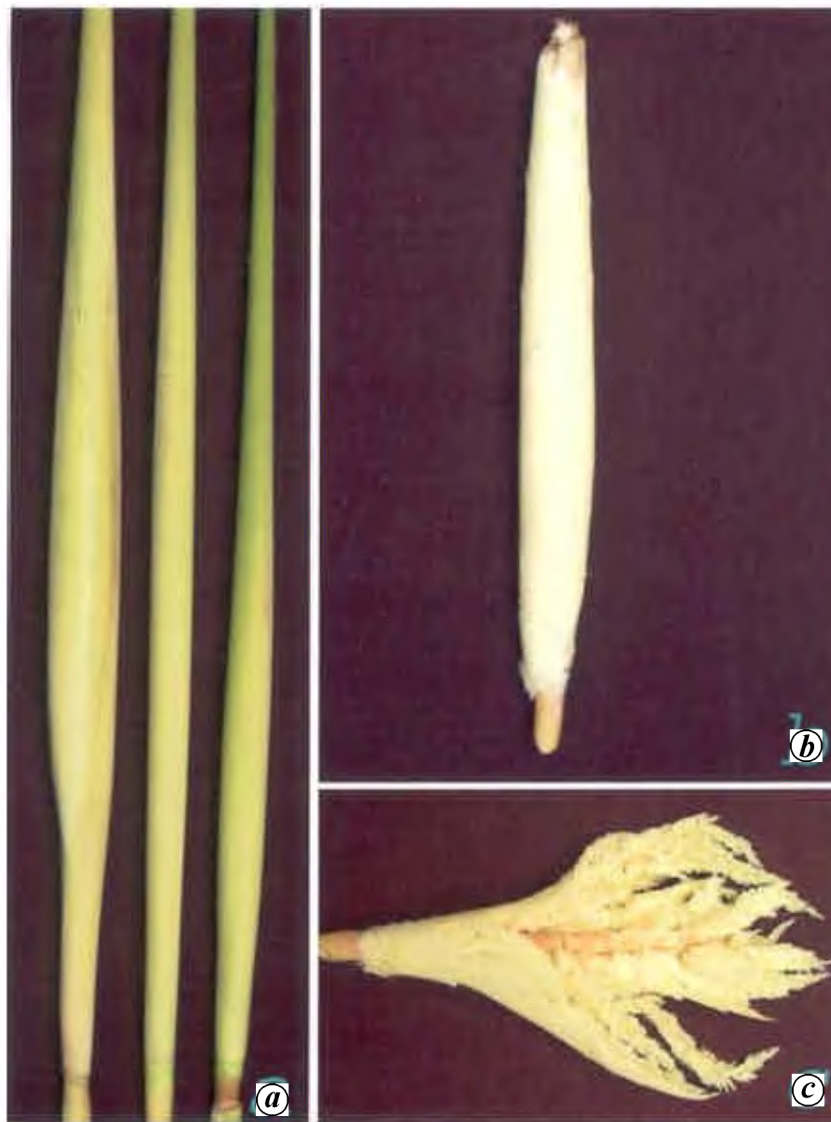


Figure 1. The inflorescence of *Saccharum edule* clone NG 77-10. **a**, Inflorescence enclosed in leaf sheath; **b**, Inflorescence when sheath is removed and **c**, A portion of the inflorescence spread to show the proliferation of floral parts.

Lennox¹⁰ reported about *S. edule* as a group of canes widely seen in New Guinea which fail to form normal tassels and 'like cauliflower, this type produces an edible head of malformed and condensed flowers and branches which fails to emerge'. It was eaten by the natives as a vegetable after boiling or roasting it in its enclosing leaf sheath. These varieties resembled *S. robustum* in cane and leaf morphology and suggested to be mutants of *S. robustum* which were vegetatively propagated by the natives for the edible inflorescence^{10,11}. Grassl¹² proposed the origin of *S. edule* by hybridization of *M. floridulus* with *S. robustum*. Based on the cytological studies of different *S. edule* clones it was suggested that a mutation at the level of single chromosome or gene in New Guinea forms of *S. robustum* and its derivatives would have resulted in *S. edule*⁸.

Considerable variability among the different clones of *S. edule* under cultivation indicated that no single origin would be sufficient for the cultivation of this group¹³. These may be selections from the naturally occurring abortive forms. During the sugarcane expedition to Melanesia, *S. edule* was found in association with *S. officinarum* in the subsistence gardens of New Guinea¹⁴. A case of occurrence of normal inflorescence on a *S. edule*, resembling that of *S. officinarum* – *S. robustum* was also reported. The *S. edule* clones 28 NG 82, 28 NG 201, 28 NG 272, IJ 76-312, IJ 76-329, IJ 76-337, IJ 76-338, IJ 76-360, IJ 76-375, IJ 76-422, IJ 76-552, IJ 76-119, NG 77-10 and NG 77-235 are being maintained at the field gene bank of sugarcane at Sugarcane Breeding Institute Research Centre, Kannur (Kerala). These clones resemble *S. robustum* in cane and leaf characters and the inflorescence have the 'cauliflower' phenotype. The details of the inflorescence of *S. edule* clone NG 77-10 are shown in Figure 1.

From the studies on floral development and floral meristem identity genes in *Arabidopsis*, cauliflower, maize, rice, etc., it is well known that the floral genes are highly conserved in plants^{15,16} and the genes determining floral development in *Saccharum* also may be the same or orthologs of them. The cauliflower-like inflorescence in *S. edule* can be due to *cal* and *ap1* mutants or its orthologs in *S. robustum*. So, the clones classified under *S. edule* did not warrant the species status.

In commercial sugarcane (*Saccharum* spp. hybrid) varieties the time and intensity of flowering are important as they influence the yield and quality of cane. The cane yield is reduced by cessation of cane growth in flowering canes and hence profusely flowering clones are not preferred for commercial cultivation, especially when used for late season crushing. The aborted inflorescence as in *S. edule* was not reported in progeny of any commercial sugarcane varieties even though a large number of crosses are being made every year and a huge number of plants were evaluated in different countries for identification of superior sugarcane clones. With identification and cloning of the genes responsible for the cauliflower phenotype of inflorescence as in *S. edule*, it will be possible to manipulate the flowering genes in commercial sugarcane varieties and the cauliflower phenotype can be brought in them. Many of the popular sugarcane varieties are flowering and have large inflorescences. If such inflorescence can be modified to cauliflower phenotype, one more economic product can be obtained from sugarcane, which can improve the profitability of sugarcane farming. As in the case of baby corn, which has become a favourite vegetable, 'cane flower' also can be a popular vegetable in the non-traditional areas.

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Received 20 April 2006; accepted 20 June 2006

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