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RESEARCH ARTICLE

Morphological and Anatomical Characterization of Dewlap in Polycross Progenies of *Saccharum robustum* Brandes & Jesw. Ex Grassl.

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Interspecific hybridization is the backbone of sugarcane improvement and the most widely used species have been *Saccharum officinarum* and *S. spontaneum.* Contribution of the other wild species *S. robustum* to the modern sugarcane varieties has been negligible due to the poor agronomic and quality traits coupled with susceptibility to diseases like mosaic and smut. The utilization of red-fleshed *S. robustum* gained a certain level of recognition due to its high polyphenol and anti-oxidant content with potential health benefits associated with it. The current study was undertaken to ascertain the morphological and anatomical variability in dewlap within a set of 20 progenies of red-fleshed *S. robustum.* The red-fleshed *S. robustum* have dark purple coloured dewlap which was inherited in their progenies with a little variation to its colour. However, the progenies showed wide variation in dewlap shape, size, cell composition and arrangements. The organization of vascular bundles, distribution of silica cells, cork cells, and hairs varied between the progenies. The correlation of anatomical traits with yield and quality traits showed that abaxial hairiness on dewlap was positively correlated with pol% but long cells on epidermis were negatively correlated with cane thickness, single cane weight and cane length. This paper discusses the variation for morphological and anatomical traits of dewlap and its usefulness in the crop improvement programsof sugarcane.

Key Words: Anatomy, Dewlap, Characterization, Sugarcane, Wild species

Introduction

Leaf blade and leaf sheath are two characteristics distinct parts of a sugarcane leaf. The blade and the sheath are separated by leaf joints. The leaf joint has two wedge-shaped structures known as a dewlap which provide mobility for leaf orientation. Predominantly there are three basic shapes of dewlap comprising rectangular, deltoid and ligular. The well-defined, easily observable and stable characteristics of the dewlap have enabled a range of systematic studies in sugarcane (Artschwager, 1951). However, the structure and inheritance of dewlap have not been researched so far. *Saccharum robustum* Brandes and Jeswiet ex Grassl, a wild species, is known to have exhibiting wide adaptability to various abiotic stresses, (drought and salinity) and a few clones for biotic stresses (Vasantha *et al.,* 2017, Viswanathan *et al*., 2017). Rakkiyappan *et al.,* (2012) demonstrated high antioxidants content in the red-fleshed *S. robustum,* which enhanced its further utilization in breeding programmes. The current study was undertaken to investigate the morphological and anatomical variability in dewlap within a set of inter-specific progenies of *Saccharum.* The study further sought to establish the anatomical difference between the various parts of the leaf *ie.,* leaf lamina, midrib, dewlap and leaf sheath.

Materials and Methods

The present investigation was carried out at ICAR-Sugarcane Breeding Institute Research Centre, Kannur (11º53'2708.7"N, 75º22'2728.4"E). Twenty progenies from two polycrosses of red-fleshed *S. robustum* clones (NG 77-84 and NG 77-76) acquired through the pollen grains from 16 different clones of *S. officinarum* (Chandran *et al.,* 2020) were used as the experimental material. These progenies were planted in a plot size of 10 ft × 2 rows with a spacing of 90 cm between the rows and 10 cm between the plants in three replications. Data were recorded on agro-morphological and quality traits at 11th month after planting. Both the colour and shape of the dewlap were recorded on first fully expanded leaf and an RHS (Royal Horticultural Society) colour chart was used for recording colour. For measuring the surface area, the dewlap region of the fully opened leaves (N+1) from actively growing sugarcane (7 month old

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crop) were used. The leaf was sampled and two pairs of dewlap was dissected out by cutting through the visible margin using a sharp razor blade from two different shoots of same age. The excised dewlap was placed on a graph paper and area calculated by counting the squares occupied by the dewlap. Hair groups 51, 51a, 52, 53, 55 58 and 58a and 65 (Artschwager,1951) were observed and scored "1" for presence and "0" for absence. For the morphological and anatomical description, the terminology and descriptor states were adopted from Artschwager (1951). The epidermis was separated by digesting tissue with nitric acid with a pinch of potassium chlorate. For cross-sectional anatomy of leaf parts, free hand sections were obtained and stained with safranine and mounted in 1% glycerin. The anatomical structures were observed under a compound microscope (Zeiss Primostar, Carl Ziessmicroscopy Pvt. Ltd). Measurements of anatomical traits were taken at 20X magnification using ocular micrometer and the data on epidermal anatomy and yield and quality traits were analyzed using the statistical software package SPSS 16.

Results and Discussion

I. Morphology of Dewlap

Dewlaps are different in different varieties of sugarcane and its structure is used for taxonomic classification. In the present work colour of the dewlap was not much varied between the progenies. But the size of the dewlap and the distribution of hairs showed wide variation.

Colour

Seventeen progenies had dark purple (Colour code-183A) dewlap similar to the maternal parent, while 3 progenies were with purple (Colour code -183C) dewlap (Table 1. The commercial hybrid used for comparison had purplish green dewlap. Artschwager (1951) opined that the colour of dewlap may vary considerably between varieties and even along one stalk the color may changes as they mature. Such development was observed in our studies as well. Among the progenies studied, colour of the dewlap did not show much variation. Majority of the population (85%) had same colour to the dewlap of that of female parent and only three progenies showed less intensified colour for the dewlap showing poor segregation for this trait.

Shape

Nine different types of dewlaps were observed in progenies based on its shape (Fig. 1).

The dewlap surface is slightly ruffled and the resulting softer structure often causes older dewlaps to break and tear (Artschwager, 1951). Artschwager

Table 1. Shape and colour of the dewlap in 20 progenies and two parental clones and a control

S.No	Clone	Female parent	Shape of dewlap	RHS colour code	Colour
1	GUK 14-7	NG 77-84	Tall deltoid subcrescent	183 A	Dark Purple
2	GUK 14-16	NG 77-84	Squarish sub crescent	183 A	Dark Purple
3	GUK 14-30	NG 77-84	Ligulate subcrescent	183 A	Dark Purple
4	GUK 14-33	NG 77-84	Descending narrow deltoid crescent	183 A	Dark Purple
5	GUK 14-41	NG 77-84	Ascending medium-tall ligulate	183 A	Dark Purple
6	GUK 14-48	NG 77-84	Ascending narrow ligulate	183 A	Dark Purple
7	GUK 14-69	NG 77-84	Tall deltoid subcrescent	183 A	Dark Purple
8	GUK 14-129	NG 77-84	Ligulate subcrescent	183 A	Dark Purple
9	GUK 14-130	NG 77-84	Equilateral deltoid	183 A	Dark Purple
10	GUK 14-675	NG 77-84	Squarish sub crescent	183 C	Purple
11	GUK 14-722	NG 77-84	Tall and short squarish-subcrescent	183 A	Dark Purple
12	GUK 14-732	NG 77-84	Squarish sub crescent	183 A	Dark Purple
13	GUK 14-734	NG 77-84	Ascending narrow ligulate	183 A	Dark Purple
14	GUK 14-745	NG 77-84	Ascending medium-tall ligulate	183 C	Purple
15	GUK 14-754	NG 77-84	Squarish sub crescent	183 A	Dark Purple
16	GUK 14-755	NG 77-84	Ascending medium-tall ligulate	183 A	Dark Purple
17	GUK 14-804	NG 77-76	Squarish sub crescent	183 A	Dark Purple
18	GUK 14-829	NG 77-76	Tall and short deltoid-crescent	183 C	purple
19	GUK 14-836	NG 77-76	Tall and short deltoid-crescent	183 A	Dark Purple
20	GUK 14-864	NG 77-76	Tall and short deltoid-crescent	183 A	Dark Purple
21	NG 77-76	fp	Ligulate subcrescent	183 A	Dark Purple
22	NG 77-84	fp	Ligulate subcrescent	183 A	Dark Purple
23	Co 86032	Control	Equilateral deltoid	137C	Purple green

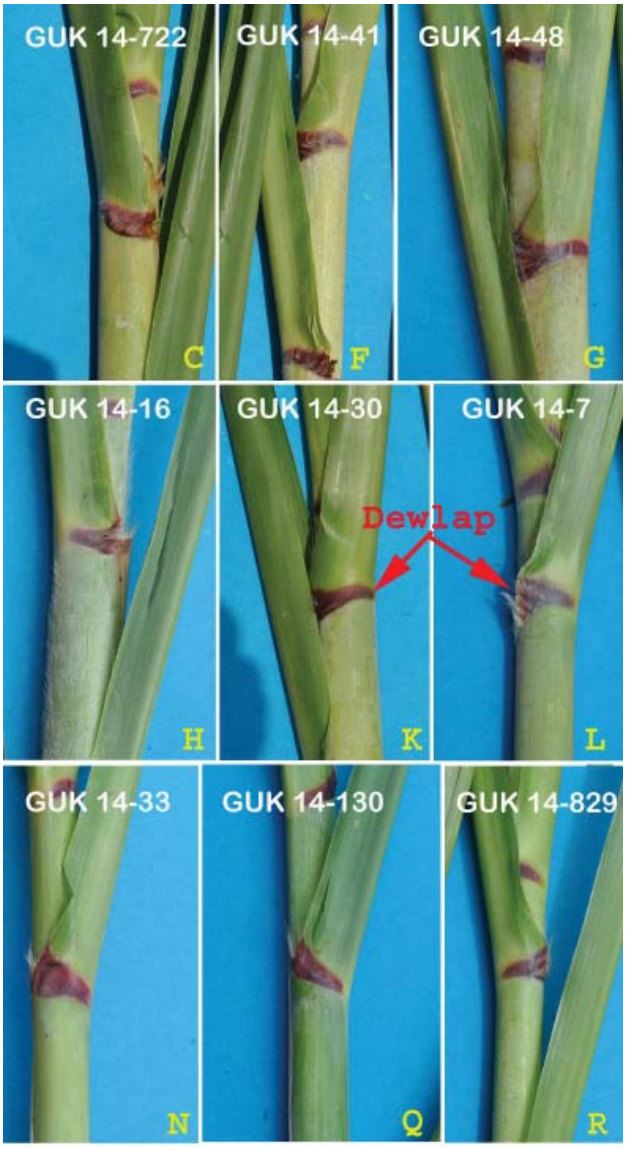

Fig. 1. Shapes of Dewlap
(C = Tall and short squarish-subcrescent, F = Ascending medium-tall ligulate, G = Ascending narrow ligulate, H = Squarish-subcrescent, K= Ligulate-subcrescent, L = Tall deltoid-subcrescent, N = Descending narrow deltoid-crescent, Q = Equilateral deltoid, R = Tall and short deltoid-crescent)

(1940) and Glyn (2004) recognized three main types of dewlaps. The rectangular or squarish type, the deltoid or triangular type, and the ligular type. All the three main types were observed in the progenies studied (Table 1). In addition, there were many intermediary forms. Nine types of dewlap were observed of the 20 types described in sugarcane by earlier workers. The result indicated that good segregation occurred for dewlap shape and other anatomical characters.

Size of Dewlap

In the check variety Co 86032 the dewlap area was 60.5 ± 5.3 mm² (Table 1). High variation was observed for surface area of progenies ranging from 25.8 ± 2.5 mm^2 (GUK 14-864) to 233 ± 8.8 mm^2 (GUK 14-734). The area of dewlaps in the female parents was 108.5 ± 10.4 mm² and 110.5 ± 10.3 mm² respectively for NG 77-76 and NG 77-84

Pubescence on Dewlap

The occurrence/distribution of hairs was on both adaxial and abaxial side of the dewlap.

Abaxial surface (Outer surface): Two types of hairs were present at abaxial surface of the dewlap viz., 58 and 58a (Table 2). 58 groups of hairs are short, felt like and often hidden under a layer of wax.

Most of the progenies had the hair group 58, except GUK 14-836 and GUK 14-864. 50% of the progenies had the hair group 58a. 10 progenies had both 58 and 58a hair groups, and ten had either 58 or 58a hair groups. There was no clones are free of both hair groups. The female parent NG 77-76 and the cultivated variety Co 86032 had both the hair groups 58 and 58a. Whereas, the female parent NG 77-84 had only 58 hair group.

Adaxial surface (Inner surface): The adaxial surface of dewlap had short felt like hairs, which is covered by long silky lashes towards the outer edge. The margin of the leaf just above the dewlap had shorter hairs that change into spine in the higher parts. Inner hairs are mainly five groups viz., 51, 52, 55, 63 and 65. The hair group 52 were short hairs usually cover the entire surface of dewlap.

Hair groups 51 and 51a were present in all 23 genotypes. Hair groups 52 was present in almost all genotypes except in female parent NG 77-84, and in the progenies GUK 14-129, GUK 14-745, GUK 14-754, and GUK 14-864. Hair group 65 present in five progenies GUK 14-16, GUK 14-30, GUK 14-41, GUK 14-48, GUK 14-755 and in the female parent, NG 77-84. In twelve progenies only 51, 51a, and 52 hair groups were present. Hair group 53 was observed only in two progenies (GUK 14-41 and GUK 14-48) and hair group 65 in three progenies (GUK 14-16, GUK 14-30 and GUK 14-755). There was no progenies with all the five group of hairs, but three main groups were present in five of them, viz., GUK 14-16, GUK 14-30, GUK 14-41, GUK 14-48, and GUK 14-755. Hair group

Table 2. Surface area and anatomical features on adaxial and abaxial epidermis of dewlap

S.No	Clone	Surface area (mm^2)	Adaxial surface				Abaxial surface				
			NLC	No. of cork cell	S-deposit	Hairiness	NLC	No.of silica cell	No.of Cork cell	S-deposit	Hairiness
1	GUK 14-7	162.0±11.3	400.0±9.0	0.0	1	3	79.7±2.9	32.0±5.1	26.0±6.2	3	1
2	GUK 14-16	227.5±9.4	325.0±6.2	0.0	0	0	109.0±8.5	47.7±7.0	24.0±4.0	2	1
3	GUK 14-30	172.3±6.1	134.7±9.0	0.0	1	3	80.0±7.9	55.7±5.2	49.3±4.6	0	0
4	GUK 14-33	177.5±6.7	227.0±9.4	0.0	1	3	123.0±5.0	11.3±2.5	100.0±9.9	0	2
5	GUK 14-41	135.5±8.9	271.7±5.0	0.0	1	3	136.0±3.3	118.3±9.8	150.7±9.7	0	1
6	GUK 14-48	106.2±10.4	97.0±5.0	0.0	1	3	127.3±5.6	105.7±4.5	93.0±2.4	0	2
7	GUK 14-69	160.8±11.1	80.0±2.0	0.0	1	3	115.0±5.0	91.7±3.1	70.7±4.9	1	3
8	GUK 14-129	164.7±11.4	218.0±2.0	0.0	0	3	232.7±4.1	4.0±0.3	30.7±6.6	2	1
9	GUK 14-130	115.7±10.1	139.7±7.8	5±0.5	1	3	108.7±2.5	107.0±3.7	44.0±5.9	2	1
10	GUK 14-675	88.3±10.0	179.0±7.0	0.0	1	2	92.5±7.5	75.7±6.6	70.7±8.4	1	2
11	GUK 14-722	63.8±4.9	195.0±5.0	0.0	1	3	60.7±5.2	24.0±3.7	4.0±1.6	1	3
12	GUK 14-732	76.3±5.6	66.0±2.0	0.0	3	3	53.0±6.2	14.7±3.4	20.7±4.1	1	2
13	GUK 14-734	233.0±8.8	226.7±5.0	0.0	1	1	67.0±5.0	61.0±8.8	16.3±7.6	3	3
14	GUK 14-745	152.0±8.3	230.0±7.5	18.0±2.5	1	1	135.3±5.2	62.7±5.0	76.3±2.6	0	1
15	GUK 14-754	115.8±6.5	248.5±6.5	0.0	1	2	118.0±5.9	80.7±0.9	38.0±9.1	1	3
16	GUK 14-755	175.8±8.8	188.0±8.0	0.0	1	2	118.7±8.2	56.0±6.7	42.3±4.8	2	1
17	GUK 14-804	89.8±9.3	208.0±8.0	5.5±1.0	1	3	140.0±5.0	52.0±4.9	78.0±5.9	2	1
18	GUK 14-829	76.8±6.2	198.7±7.7	12.5±3.0	1	2	151.3±8.4	138.7±9.3	90.7±8.1	1	1
19	GUK 14-836	29.0±2.9	265.3±7.5	0.0	1	2	117.5±2.5	71.0±2.9	64.3±5.4	1	1
20	GUK 14-864	25.8±2.5	262.0±9.9	0.0	1	2	154.7±6.2	108.0±8.6	37.7±6.1	1	0
21	NG 77-76	108.5±10.4	200.0.±8.2	0.0	1	3	150.0±5.0	146.7±4.8	72.0±2.8	3	0
22	NG 77-84	110.5±10.3	169.3±7.4	15.0±3.0	1	3	64.5±0.5	57.0±4.6	72.0±8.6	1	2
23	Co 86032	60.5±5.3	106.0±0.5	0.0	1	3	36.0±7.1	29.0±3.6	26.3±8.5	1	3

NLC= Number of long cells; S-deposit= Silica deposit (Graded 0 to 3 Scale) ; Hairiness=Graded 0 to 3 scale

51 and 51a were present in five progenies viz., GUK 14-129, GUK 14-745, GUK 14-754,and GUK 14-864 and in the cultivated variety Co 86032 but other hair groups were totally absent. Between the female parents difference was observed in the hair group distribution, in NG 77-76, hair groups 51, 51a and 52 were present, while in NG 77-84 hair groups are 51, 51a, and 65 were present.

The pubescence on dewlap of sugarcane was described by Artschwager (1951). Hair group 51,52,55,63 and 65 predominately occurs at inner side (adaxial) in sugarcane. All these groups were observed in the progenies. Hair group 52 that present mainly at inner dewlap surface which was sparse to dense, 51 and 51a are short hairs to long hairs occurs marginally or occasionally entire. Another hair group 65 was found in juxtaposition with the ligule which forms a file of long or medium long hairs at the base of the ligule extending between leaf edge and midrib.

The dewlaps are devoid of clear venation as generally observed in sheath and blade, the dorsal hairs appear uniformly scattered but rarely found distributed in a banded pattern. When there is only sparse distribution they are mainly confined to the marginal zone, but rarely they are dense near the midrib. The hairs on outer surface are short and appressed but rarely more prominent. When semi-long hairs of group 58 are observed on the outer dewlap surface, there will be more pronounced, and long hairs on the inner surface as well (Artschwager, 1951). The second type of hair group is 58a, which are long and reported for the first time by Artschwager (1948) in clones of *S. spontaneum* and *S. robustum* and subsequently among varieties of noble canes. These hair group was also available in 12 out of 20 progenies an in one of the female parents in the present study. The hairs are long and mostly marginal and because of its marginal implantation, the genotype with this hair group had the best advantage protecting the growing point (Artschwager, 1951).

Hair group 51 are the longest and most conspicuous and over up the inner surface of the dewlap. The length of it gradually decreases towards the midrib region. Hair group 52 was also described by Artschwager (1951) for the first time, which are medium long and starting from

the base to higher up in the dewlap. All the progenies, the parents and the check varieties had these hair group indicating its universal presence in most of the genotypes. Hair group 65 forms a single row of hairs not growing the above the ligule height but extended between leaf edges. The hair group 55 was found behind the midrib but rarely across the midrib (Artschwager, 1951). Our studies showed that the hair group65 was present only in three progenies and the hair group 55 only in two progenies indicating their rare occurrence.

II. Leaf Anatomy

The anatomical features of lamina, midrib, dewlap and leaf sheath showed considerable difference between them, though they are part of same organ, the leaf. The intensity of trichomes also varies between lamina and leaf sheath and dewlap.

CS of lamina

In lamina, the epidermis was not continuous, but interrupted by stomata. The distance between the vascular bundle was relatively smaller than leaf sheath and lamina (Fig. 2). The vascular bundles are of three kinds, they are large, medium, and small as reported earlier (Joarder *et al*., 2010). The small bundles are situated near the lower epidermis, while the large and medium ones were found in the center of the leaf blade. The small and medium sized bundles occur between the large bundles and alternate with one another. Sugarcane is a C4 plant which follows the Kranz anatomy having photosynthetically active chlorenchymatous bundle sheath. The vascular bundle consists of phloem and xylem. The xylem of the large bundle is fully developed and consists of two large meta xylem vessels and a number of small elements. In the smaller bundles the xylem is greatly reduced in size.

In the midrib region thick layer of parenchyma tissue was found between the fibro-vascular bundles and the upper epidermis; hence, all vascular bundles in this part of the blade were restricted to the lower side of bundles, is reinforced by a thick solid layer of sclerenchyma. The

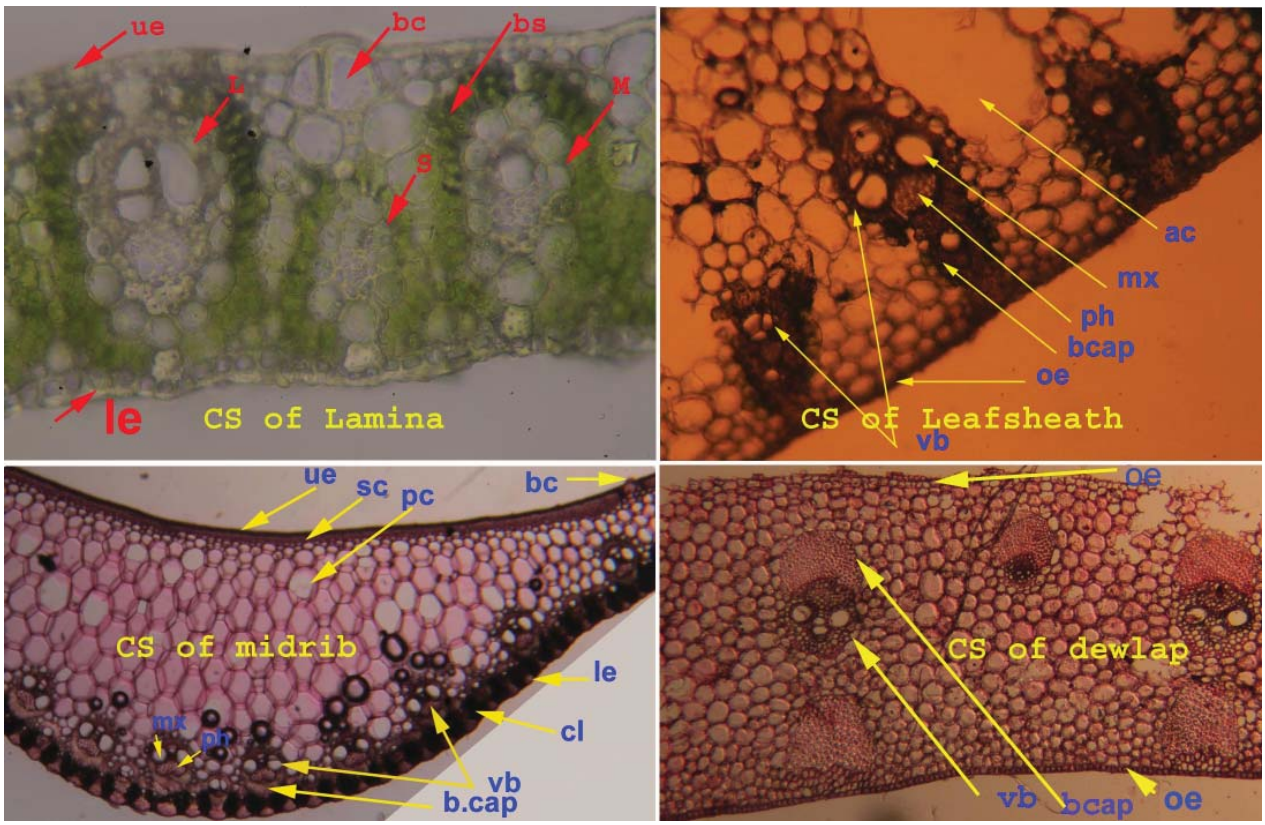

Fig. 2. CS of leaf at lamina, dewlap, mid rib and leaf sheath
(ue = Upper epidermis, L = Large vascular bundle, M = Medium size vascular bundle, S = Small vascular bundle, bc = Bundle cap, bs = Bundle sheath, ac = Aerenchyma, mx = Metaxylem, ph= Phloem, oe=Outer epidermis, vb= Vascular bundle, e=Epidermis, sc=Sclerenchyma, pc = Parenchyma, cl = Chlorenchyma, le = Lower epidermis)

layer of parenchyma which is found between the bundles and the upper epidermis does not contain chlorophyll and the white color of the upper side of the midrib was attributed to it, but greener at the lower side as a result of the presence of chlorophyll-bearing cell adjacent to the lower epidermis.

CS of Leaf Sheath

A cross section at about half way the length of the sheath shows radial rows of fibro vascular bundles. Unlike the mid rib the largest bundles are located at about equal distance both from the upper and lower epidermis. Towards the outer epidermis (morphologically the lower surface) the bundles gradually became smaller. The number of vascular bundles in a one radial row varies from 2 to 4. In the parenchymatous tissues, in which the bundles are embedded, showed large cavities alternating with the radial rows of bundles. In some cases several vascular bundles are often found united into one large composite bundle in such cases the composite bundle is surrounded by a sclerenchymatous layer of cells which extends from the radial vascular bundle row towards the upper epidermis.

CS of Dewlap

As in other portion of the leaf the epidermis is single layered but epidermal cells are not interrupted by stomata. Vascular bundle of leaf blade, leaf sheath, and dewlap are different in their arrangements. In leaf sheath a large bundle constitute of two single bundles, where towards the dewlap one of the bundle is gradually disappears. In dewlap mature vascular bundle have bundle cap which is collenchymatous. Vascular bundles are of three types large, medium, and small which is alternates with one another. And the parenchyma cells, seen in between vascular bundles. Vascular bundles are seen towards the abaxial (outer) surface of epidermis. Bundle cap present only opposite to the large vascular bundle. Large vascular bundles consist of large xylem vessels. In dewlap chlorophyll pigments present in epidermal layer, bundle sheath, and in the upper layer parenchyma cells but often masked by the anthocyanin pigment which give dark purple color to the dewlap region in the progenies.

In sugarcane most of anatomical the features of taxonomic value are associated with the leaf blade (Metcalfe 1960) and hence detailed anatomical studies have been reported initially in leaf blade and subsequently the studies were extended to understand the detailed vasculature of the leaf and its parts (Artschwager 1925, 1940; Van Dillewijn, 1952, Martin, 1961). The present study on cross section of lamina, midrib, dewlap and sheath conforms with the previous reports on the differences between the four parts of the leaf on vascular tissues, mechanical tissues and in their arrangements. Dewlap was characterized by the absence of stomata and collenchymatous bundle sheath bundle caps are seen only for larger vascular bundles. Cobert and Evert (1982) also reported the collenchymatous bundle cap in dewlap of sugarcane. The collenchymatous bundle caps substantiate the flexibility (Artschwager 1951) offered to the dewlap for orientation of the lamina during the early stages of leaf development. The dewlap was also reported to be cracked, disfigured or withered while leaf attaining maturity and the same was observed in the present studies.

At midrib region the size of the bundles gradually decreases from the inner band (next to the inner epidermis) to the outer one (Van Dallewijn, 1952). Isaac (1939) observed that varieties which are resistant to the top-borer, *Scirpophaga nivella* F., are characterized by strong and hard midrib, whereas those which are susceptible to top-borer possessed weak midribs. *S. robustum* in general and more particularly the red fleshed *S. robustum* belongs to the forma *sanguine* had broad leaf and thick midrib and so as the progenies. But further studies may be required to understand the extent of the sclerenchymatous sub-epiderma layer in the midrib region and the top borer screening in these progenies to confirm the results. Rao (1947) by studying the anatomy of some fifty varieties of sugarcane was able to confirm the observation of Isaac (1939). Cobert and Evert (1982) found that the leaf sheath has a lesser number of vascular strands compared to lamina as a result of the fusion of vascular strands at the leaf joint. Towards the dewlap, the sheath is narrower and has more thickness and the air cavities gradually reduce and finally disappear. There are single vascular bundles that are generally larger and arranged alternately with the composite vascular bundles.The cross-section of the lamina and leaf sheath showed difference in the number of vascular bundles and fusion of more than one vasculature in leaf sheath region. However, earlier studies (Colbert and Evert,1982) showed that, the cross-sectional areas are rather increasing to both sieve tubes and tracheal elements while it continues to leaf sheath. Hence, the reduction in number of the vascular bundles does not affect the translocation of water and food between the

leaf parts. The inner epidermis consists of cells of various sizes indicating the divisional or cambial activity at the dewlap region though cambial activity in mature leaves was not a regular feature of monocot leaves. This is in conformation with the earlier report on the anatomy of leaves by Moreland (1942) showing cambial activity in leaves of monocots and later by Artschwager (1951). He also observedthe development of secondary meristem as an extension of cambium from one vascular bundle to another and opined that monocotyledonous plants share similarities to dicots in these aspects.

Epidermal anatomy of the dewlap

Epidermis comprised of hexagonal cells not interrupted by stomata. In addition to the normal long cells, silica cells, various forms of silica depositions, cork cells and dried cells constitute the epidermis. Trichomes also observed on epidermal cells.

Abaxial (outer) epidermis: Dried cell is absent in abaxial (outer) surface of epidermis (Fig. 3). Stomata was generally absent but a few stomata were observed in GUK 14-130. Number of normal cells is varying in different genotypes, the highest number of cells per unit area was observed in GUK 14-129 (232.7±4.1), and the lowest in cultivated variety Co 86032 (36.0±7.1, Table 2). The female parents NG 77-76 have 150±5.0 and NG 77-84 had 64.5 ±0.5 normal cells. Silica cell was present profusely on abaxial surface. Highest number of silica cell was found in female parent NG 77-76 (146.7±7.8) and the lowest number in check variety Co 86032 (4±0.3) The female parent NG 77-84 had 57 silica cells per unit area. Cork cells were present on abaxial surface of all genotypes. The female parents NG 77-76 and NG 776-84 had 72±2.8 and 72±8.6 cork cells respectively. Highest number of cork cell (150.7±9.7) was observed in GUK 14-41 and lowest number (4±1.6) in GUK 14-722. The cultivated variety Co 86032 had 26.3±8.5 cork cells.

Silica deposition was high (scale=3) in female parent NG 77-76 and low (scale=1) in NG 77-84and cultivated variety Co 86032. Medium deposition (scale=2) of silica were found in five progenies and low (scale =1) in eight progenies. In progenies viz., GUK 14-745, GUK 14-30, GUK 14-33, GUK 14-41 and GUK 14-48 the silica deposit was completely absent (Scale=0). Apart from NG 77-76, high silica deposits were found in GUK 14-7, and GUK 14-734. Number of hairs were less on abaxial surface compared to that of adaxial surface. Hairs were completely absent on abaxial surface of GUK 14-30, GUK 14-864 and the female parent NG 77-76. In ten clones, hairs were low (scale=1), five clone has medium hairs (scale=2), and another five clones had profuse hairs (scale 3). NG 77-84 female parent had medium hairs and the cultivated variety had profuse hairs on abaxial surface of the dewlap.

Adaxial (inner) epidermis: Silica cells and stomata were completely absent on the adaxial (inner) surface (Fig. 4) however, silica depositions of various shapes were present. Low distribution (scale 1) of silica deposition was found in for most of the genotypes, except GUK 14-732 where it was very high (scale 3). Silica deposition was completely absent in GUK 14-16 and GUK 14-129. The highest number (400±9.0) of long cell was found

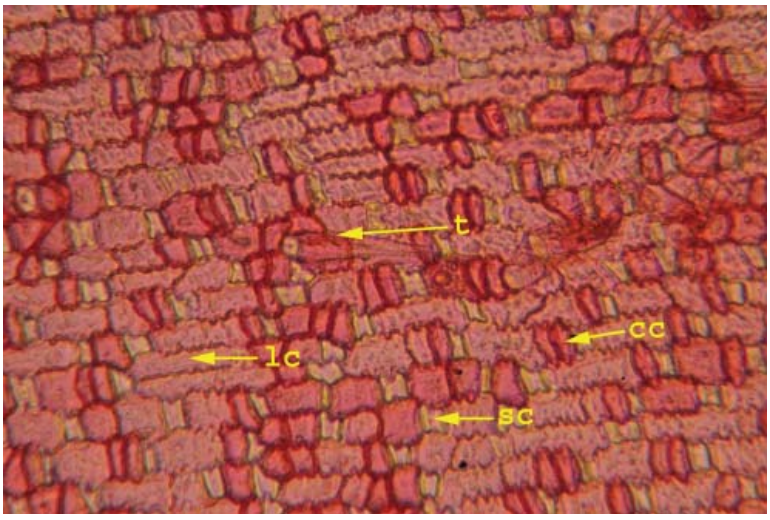

Fig. 3. Abaxial epidermis of GUK 14-48
(t= Tannin cells, lc=Long ells, cc = Cork cells, sc= Silica cells)

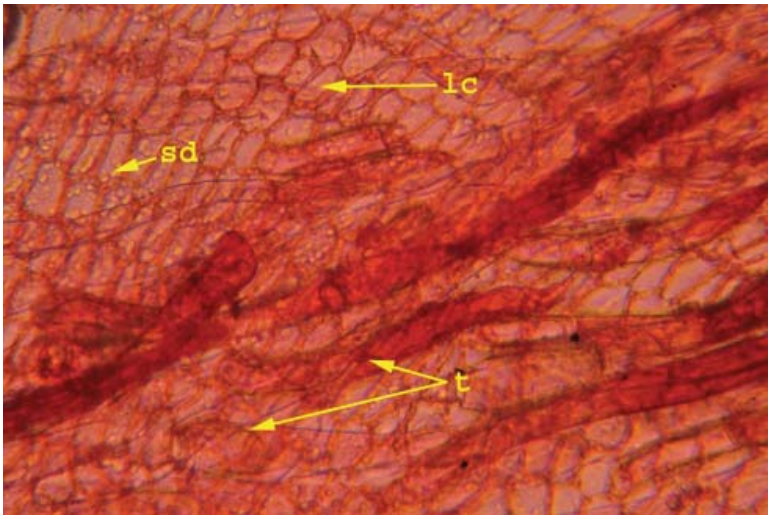

Fig. 4. Adaxial epidermis of GUK 14-48
(lc=Long cells, sd= Silica deposits, t= Trichomes)

in progeny GUK 4-7 and the lowest (66±2.0) in GUK 14-732. Long cells in female parent NG 77-76 was 200±8.2 and NG 77-84 was 169.3±7.4, and in cultivated variety Co 86032 had 106±0.5. Cork cell only present in five progenies, they are GUK 14-84, GUK 14-130, GUK 14-745, GUK 14-804, and GUK 14-829.

Distribution of hairs on the adaxial (inner surface) surface of the dewlap also showed wide variation between progenies. Hairs were totally absent in GUK 14-16 where as 11 progenies, cultivated variety (Co 86032) and both female parents had a dense distribution of hairs (scale =3, Table 2). Six progenies had profuse hairs (scale =2) and two progenies had a sparse distribution of hairs (scale =1). In addition to these cells, some of the progenies (GUK 14-16, GUK 14-41, GUK 14-130, and GUK 14-864) showed brown coloured cells which appears to be ruptured and dried cells.

The distribution of silica cells, cork cells, hairs, and other deposition vary between the genotypes. Silica cell provides mechanical stability to the tissues, it protect against fungi, insects and other herbivores. It also help to facilitate light interception, drought resistance and problems related to nutritional disorders including excess availability (Motomura *et al*., 2006). The progenies with high silica cells viz., GUK 14-41, GUK14-48, GUK 14-130. GUK 14-829, GUK 14-86 are the potential genotypes for evaluating against different stresses.

III. Correlation studies

Two-tailed correlation analysis based on Pearson coefficient was done for 18 characters. A significant positive correlation was observed for germination with number of millable canes (0.731**), HR brix at Middle of the cane (0.430*, Yield (-0.484*) but negatively correlated with cane thickness (-0.479*) and single cane weight (-0.505*). A similar positive correlation was also found between NMC and other quality traits (Table 3). This confirms the earlier result from the evaluation of a large number of progenies at the ground nursery level (Chandran *et al*., 2020) with unreplicated data. HR brix at bottom was positively correlated with HR brix at Middle (0.933**), bottom and top (0.891**) and at Brix at 11th month (0.797**) and Pol % (0.786**) at 11th month. The number of long cells on the epidermis per unit area was negatively correlated (-0.590*)with cane thickness, single cane weight (-0.448*)and cane length (-0.454*). Hairs on the adaxial surface of dewlapwere negatively correlated (0.419*) with adaxial long cells. Another interesting correlation observed was between abaxial hairiness on dewlap with pol% (0.434*). Abaxial hairiness was negatively correlated with adaxial hairs (-0.505*). Abaxial silica cell was positively correlated with abaxial cork cells (0.503*)as in most of the cases, the cork cells and silica cells were observed in pairs. The significant positive correlation of abaxial hairiness on dew lap with pol%, negative correlation with number of long cells on epidermis with cane thickness and single cane weight and cane length can be used for selecting the progenies for further crop improvement programme of interspecific crosses.

Sugarcane leaf composed of leaf blade or lamina and leaf sheath. At the junction of the lamina and leaf

Table 3. Correlation of agronomical, quality and anatomical traits of 20 progenies, female parents and check variety

	30d	NMC	Ctk	HRBB	HRBM	HRBT	Ext	Scwt	CL	Brix	Pol	Yld	ADNC	ADH	ABNC	ABS	ABC	ABH
30d	1.000																	
NMC	**0.731****	1.000																
Ctk	**-0.479***	**-0.535****	1.000															
HRBB	0.318	**0.523**	-0.272	1.000														
HRBM	**0.430***	**0.557****	-0.198	**0.933****	1.000													
HRBT	0.406	**0.517***	-0.173	**0.891****	**0.978****	1.000												
Ext	0.121	0.090	**0.475***	-0.011	0.219	0.318	1.000											
Scwt	**-0.505***	**-0.627****	**0.829****	**-0.458***	-0.396	-0.351	0.370	1.000										
CL	-0.198	-0.047	0.081	-0.159	-0.162	-0.088	0.150	0.009	1.000									
Brix	0.308	**0.420**	-0.028	0.797	**0.877****	**0.870****	0.297	-0.270	-0.052	1.000								
Pol	0.279	**0.422**	-0.031	**0.786***	**0.854****	**0.852****	0.301	-0.282	-0.059	**0.987****	1.000							
Yld	**0.484***	**0.694****	0.070	0.272	0.379	0.359	**0.528****	0.061	-0.034	0.342	0.339	1.000						
ADNC	0.403	0.369	**-0.590****	0.228	0.191	0.156	-0.203	**-0.448***	**-0.454***	-0.098	-0.077	0.109	1.000					
ADH	-0.382	-0.326	0.106	-0.233	-0.180	-0.131	-0.005	0.270	0.020	-0.123	-0.122	-0.226	**-0.419***	1.000				
ABNC	0.321	0.087	-0.242	-0.139	-0.169	-0.142	-0.120	-0.210	-0.014	-0.254	-0.290	-0.098	0.240	-0.039	1.000			
ABS	0.146	-0.141	0.069	-0.038	-0.099	-0.169	-0.177	0.064	-0.150	-0.165	-0.179	-0.119	-0.043	-0.060	0.291	1.000		
ABC	0.202	-0.033	-0.025	-0.292	-0.252	-0.247	0.027	0.163	-0.371	-0.329	-0.312	0.007	-0.026	0.210	0.359	**0.503***	1.000	
ABH	0.053	0.237	0.168	0.129	0.134	0.115	0.189	0.024	0.033	0.404	**0.434***	0.333	-0.329	0.042	**-0.505***	-0.323	-0.228	1

* significant at 5% level ** Significant at 1% level

(30d- Germination at 30 days; NMC- Number of millable canes; Ctk- Cane diameter; HRBB- HR brix at Bottom of the cane ; HRBM – HR brix at Middle of the cane; HRBT- Hr brix at top of the Cane; Ext-Juice extraction (%); Scwt- Single cane weight; CL- Cane length; Brix- Hydrometer Brix at 11^{th} month; Pol- Pol %; Yld- cane yield/plot(kg); ADNC- Adaxial normal cells; ADH- Adaxial hairs; ABNC- Abaxial normal cells; ABS-Abaxial silica cells; ABC, Abaxial cork cells; ABH- Abaxial hairs)

sheath the appendages like ligule towards the inner side and ligular process or auricle on either side and the dew lap were present. Trichomes also present at various intensities on leaf sheath, lamina and on the appendages (Artschwager, 1951). The dewlap or the leaf joint is a peculiar structure found in some the graminaceous members including sugarcane. Dewlap is located just above the ligule at the joint of leaf blade with leaf sheath. It is also referred as leaf joint/ leaf triangle. The tips or inner margins of the two blade joint hinge areas almost meet on the back surface of the midrib. The dewlaps form a hinge of theblade joint and this enablesome kind of mobility to the leaf blade and in turn, help the plant to orient the leaves. The red-fleshed *S. robustum* had a distinct dark purple coloured dewlap which is inherited to their progenies without much variation in colour that provides the advantage in identifying the interspecific hybrids. But varied for shape and size of the dewlap and for different composition of the epidermal tissues. Though the leaf sheath, dewlap and lamina constitute same organ, anatomically they are distinguishable in the size and arrangement of vascular bundles. The variation was due to its function such as for supporting provided with more bundle cap cells in leaf sheath and dewlap compared to lamina. The flexibility and strength was offered due to collenchymatous bundle cap in dewlap, sclerenchymatous bundle cap for leaf sheath and lamina and in the later with only minimal bundle cap cells. The distribution vascular bundle also varied between these regions, the vascular bundles often composite ones which are more widely placed in leaf sheath alternating with air cavities. In dewlap the vascular bundles are closer but without air cavities in between and in leaf blade it was closely arranged alternating one large vascular bundle with two smaller ones. The present study revealed the detailed structure and anatomical difference between lamina, midrib, dewlap and leaf sheath and the epidermal tissue composition of dewlap in twenty interspecific progenies developed from polycrosses on red-fleshed *S. robustum* and its usefulness in the crop improvement programme of sugarcane.

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References

Artschwager E (1925) Anatomy of the vegetative organs of sugarcane. *J. Agric. Res.* **30**: 197-221.

Artschwager E (1940) Morphology of the vegetative organs of the sugarcane. *J. Agric. Res.* **60**: 503-549.

Artschwager E (1948) vegetative characteristics of some wild forms of *Saccharum* and related grasses. US Dept. Agr. Tech.Bul.951, pp69.

Artschwager E (1951) Structure and Taxonomic value of the Dewlap in sugarcane. United States Department of Agriculture. Washington, D.C. Technical Bulletin No. 1038. October 1951. pp 1-12.

Chandran K, M Nisha and PP Gireesan (2020) Characterization of Progenies from Polycrosses of *S. robustum* Clones f. *sanguineum*. *Sugar Tech* **22(3)**: 379–388.

Colbert JT and RF Evert (1982) Leaf vasculature in sugarcane (*Saccharum officinarum* L.). *Planta* **156**: 136–151.

Glyn L James (2004) Introduction to sugarcane In: Glyn L .James (ed). *Sugarcane*, Blackwell Science Ltd . pp. 3-8.

Isaac PV (1939) How midrib hardness affords resistance to the sugarcane top-borer, *Scirpophaga nivella* F, in India. *Curr. Sci.* **8**: 211-212.

Joavder N, AK Roy, N Sima and K Pravin (2010) Leaf blade and midrib anatomy of two sugarcane cultivars of Bangladesh. *J. Bio. Sci.* **18**: 66-73.

Martin JP (1961) The anatomy of the sugarcane plant. In: Martin JP, Aboot E and Hughes CG (eds) Sugarcane disease of the world. Elsevier Amsterdam 1 pp 3-52.

Metcalfe CR (1960). Anatomy of the monocotyledons. I. Gramineae. Clarendon Press, Oxford pp 731.

Moreland CF and LH Flint (1942). The development of vascular connections in the leaf sheath of sugarcane. *Am. J. Bot.* **29**: 360-362.

Motomura H, T Fujii and M Suzuki (2006) Silica Deposition in Abaxial Epidermis before the Opening of Leaf Blades of *Pleioblastus chino* (Poaceae, Bambusoideae) *Ann. Bot*. **97(4)**: 513–519.

Rakiappan P, GS Suresha, TR Rupa, K Hari, and S Venkatesan (2012) *Prospecting sugarcane germplasm for antioxidants*. In: Proceedings of international symposium on new paradigms in sugarcane research, Oct 15–18, ICAR-SBI, Coimbatore, India pp 315–316.

Rao JT (1947) Leaf midrib structure of sugarcane as correlated with resistance to the top-borer, (*Scirpophaga nivella* F.). *Indian. J. Agric. Sci.* **17**: 203-210.

Van Dillewijn C (1952) Botany of Sugarcane. The Chronica Botanica Co, Waltham, MA pp 371.

Vasantha S, R Gomathi, S Venkataramana and R Arun Kumar (2017) Evaluation of Sugarcane Germplasm for Drought and Salinity Tolerance. *J. Sugarcane Res.***7(1)**: 35–45.

Viswanathan R, P Malathi, K Chandran and Gopi R (2017) Screening of sugarcane germplasm for red rot resistance. *J. Sugarcane Res.* **7(2)**: 100–111.