STUDY OF SOME ASPECTS OF THE PHYSIOLOGY OF THE TENDRILS OF CUCURBITACEAE

BY

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Introduction.

Dastur and Kapadia (3) have recently published a large number of observations on the growth and sensitivity of the tendrils of plants of Cucurbitaceae and they have produced some evidence in support of the physical mechanism of the curvature of the tendrils. They have shown "*that a tendril may curl as it grows but it does not curl on account of growth.*" This view is supported by four kinds of observations made by them. *(a)* The measurements of the cells with due precautions, of the tendrils, in uncurled and curled conditions, *(b)* the nature and character of cells on the two sides of the tendrils, *(c)* the concentration of extensible material in a position that would produce maximum curvature, *(d)* the concentration of dense material in uncurled tendrils to withstand the pressure of compression exerted by the elongating convex side.

They have also advanced a physical concept of the mechanism of curvature of tendrils which is a great advance on similar views expressed before. A fully grown straight tendril is in a state of tension on account of the two oppositely directed forces residing in them. The cells on the convex side have a great tendency to elongate, while the cells on the concave side do not possess that tendency. But the latter on account of dense material offer a great resistance to the convex side and prevent its units to elongate, thus they withstand bending which would otherwise be the case. The contact with an uneven surface brings about a fall in tension at one point where the contact is made and the fall in tension brings about the elongation of cells on the convex side and the curvature results. The fall in tension is probably accompanied by the passage of water into the elongating cells from the conducting elements.

As other aspects of the physiology of the tendrils which can throw light on the mechanism of curvature of tendrils have not been included in their study on Cucurbitaceae, it is undertaken to extend these observations made by them by making further investigations. Pure physiology of tendrils of any plant has not been studied before and the views so far expressed, except those of Dastur and Kapadia (3) rested more or less mainly on anatomical facts, and on the measurements made of the inkmarks on the two sides of the tendrils or of the cells on the two sides. Such investigations have so far failed to give us an insight in the working of the complex mechanism which produces such rapid curling movement. The results of such a study of different aspects of physiology of tendrils when viewed in relation to their anatomical structure may lend some clue of the internal mechanism.

If the curling movement is a physiological process caused by accelerated growth of the convex side, there should be a certain amount of expenditure of energy. If that is the case, there should be an increased amount of output of carbon-di-oxide during the time that curvature takes place, in comparison to the carbon-di-oxide evolved in uncurled and totally curled conditions. Therefore the measurements of the carbon-di-oxide evolution of straight, curling and curled tendrils may be useful in deciding whether the curling movement is a physiological or a physical phenomenon. An accelerated growth of the convex side of the tendril should be accompanied by an accelerated output of carbon-di-oxide which should continue till the curling movement goes on and the support is grasped. If the curling movement is wholly a process of physical elongation it is reasonable not to expect an increased output of CO_2 during the same period.

Similarly the measurement of the internal temperature of the straight, curling and curled tendrils should throw some light on the mechanism of curvature. It would be interesting to note if there is any evolution of energy in the form of heat, when the tendril responds to the contact stimulus.

The tendril of a Cucurbitaceous plant that has not caught a support stands always straight except for a slight curl at the apex and it remains straight as it grows and even when it becomes fully grown in length. This would suggest that it is in a turgid condition. The state of tension in the tendril, spoken of by Dastur and Kapadia (3) is very likely related to the state of turgescence of the tendril as the tendency of physical elongation of cells on the convex side is one of the causes that are responsible for the state of tension. Dastur and Kapadia (3) have shown that the sensitivity of the tendril increases as the age of the tendril advances and so also the tension in the tendril increases as it grows. It is therefore probable that the turgidity of the tendril increases as it becomes fully grown in length. The measurement of the degree of turgescence at different stages of growth is necessary to determine if the view put forward by Dastur and Kapadia (3) regarding the existence of tension is admissible. These measurements could be done in the following ways. The measurement of the water content of the tendrils at different stages of growth, per unit length and per unit dry weight, should be able to give an indirect measure of the degree of turgescence in straight tendrils.

The suction pressure of a cell is equal to the osmotic pressure of the cell contents minus the inwardly directed wall-pressure exerted by the elastic and distended cell wall. The suction pressure decreases as the cell wall is more and more distended by the absorption of water and as the wall-pressure increases. When the pressure exerted by the cell wall on the cell contents becomes equal to the outwardly directed hydrostatic pressure of the cell contents on the cell wall, the suction pressure falls to zero and no more water can be taken in the cell. In a straight tendril the suction pressure should be higher than that of the cells in the curled tendril, as the absorption of water by the cells accompanied by the distension of the cell walls of the elongating cells of the convex side on the whole should increase the wall-pressure and lower the osmotic pressure of the diluted cell contents. So the measurements of the suction pressure of the straight and curled tendrils should furnish evidence to support or otherwise the physical view of the curling mechanism.

Measurement of Respiration.

As stated in the introduction, it was decided to determine the respiration of the tendrils as it may throw some light on the physical or physiological view of the mechanism of curvature of the tendrils. The apparatus used is of a simple type, as can be seen from the following description. An air current deprived of the CO_2 is aspirated through a glass-tube about one foot long and $1\frac{3}{4}$" in diameter, which serves as a chamber for the respiratory material. The chamber is kept at the temperature of the atmosphere, as there is no great change in the temperature throughout a particular season, excluding the abnormal conditions. The chamber is supplied with a rubber cork, which bears four holes. From one of the holes a tendril, which remains attached to the plant, is enclosed. Out of the three small holes, two serve to hold inlet and outlet tubes for the aspirated air. The third is supplied with a solid glass rod, used for the purpose of stimulation of straight tendrils. After making the tube airtight with cotton and paraffin, the air is bubbled through it rapidly, in order to avoid any accumulation of CO_2 in the tube, which would interfere with the normal respiration of the material concerned. The air is deprived of CO_2 by passing it first through U-tubes containing soda-lime and then through a caustic potash tower in order to ensure complete removal of CO_2. In order that the air surrounding the tendril may remain moist, the inlet tube is made to dip in water at the bottom of the chamber. The CO_2 collected by the air current from the respiratory chamber is absorbed by NaOH solution in glass bottles supplied with two inlet tubes connected with Y-tubes. In all cases the respiratory activity is measured while the tendrils remain attached to the plants grown in the soil in the Institute garden. During the experiment the chamber is covered with a piece of black paper. The mean of the three readings is taken in determining the respiratory activity. The chief point of importance in all the experiments carried out is, that the volume of air aspirated must be the same, otherwise a great error is introduced in the results. In order to do this, it is necessary to adjust the pressure at which the air is aspirated. It is also necessary to determine the number of bubbles aspirated in a given time by adjusting the pressure. In these experiments the number of bubbles aspirated is 60 per minute.

Using this methcd the respiration of straight and curled tendrils, as well as of straight tendrils stimulated by the support of a glass rod was determined, the results of which are tabulated below.

Table I.

RESPIRATION OF LUFFA AEGYPTICA, *Mill*

Length in cms.	Dry Wt.	Rate of resp. of St. T. in m. gms.	Rate of resp. of curling T. in m gs.	Length in cms.	Dry Wt.	Rate of resp. of curled T. in m. gms.
13.3	9.0	2.29	2.03	12.2	4.4	2.03
14.5	7.8	2.28	2.84	13.7	9.2	0.39
15.5	7.4	2.86	...	...	...	...
17.5	7.5	1.99	2.05	18.6	9.5	0.38
19.5	12.8	1.13	1.35	19.1	11.6	0.30
21.6	11.2	1.46	1.20	20.1	12.1	0.36
23.6	12.4	2.17	2.05	22.9	11.2	0.37
...	...	...	...	28.2	24.3	0.24

Table II.

RESPIRATION OF CUCURBITA MAXIMA, *Duch.*

...	...	...	...	16.1	20.9	2.16
...	...	...	...	16.5	27.2	1.48
17.2	25.6	5.48	5.79	17.7	23.0	1.74
21.0	22.1	4.72	5.02	22.5	19.8	1.35
25.1	30.7	4.81	4.79	25.5	30.5	2.08
27.0	39.7	4.01	4.01	26.3	34.1	1.39
29.4	42.8	4.15	3.62	...	...	...
36.2	54.0	3.15	3.34	...	...	...
40.5	67.1	2.91	2.65	...	...	...

The results show that there is no increased output of CO_2 during the period of curling round a support. The CO_2 output is the same or less than the output of CO_2 when the tendrils were straight.

Measurement of Internal Temperature.

It was undertaken to determine the internal temperature of tendrils at different stages of growth. It is known in some cases that a certain amount of energy in the form of heat is liberated when the seedlings germinate, or when the inflorescence or flowers open. The energy that escapes in the form of heat is derived by the decomposition of substances of higher calorific value into substances of lower calorific value. The energy that is necessary in bringing about the opening in such cases is derived from the stored up respiratory materials and a part of energy is liberated in the form of heat.

The measurement of internal temperature would therefore throw some light if any energy escapes in the form of heat when the tendrils respond to stimulus of contact and begin to curl. This would occur if the curvature of the tendrils is brought about by the energy derived in a similar manner as in the above-mentioned causes. It is possible that the energy that may escape in the form of heat may be too small for measurement as evidently there seems to be no deposition of special respiratory material in the tissues of the tendrils.

The temperature of plants has been a subject of investigation with botanists. Earliest investigators used mercury thermometers pressed against the leaves, or wrapped the leaves around them. This method of determining the temperature is rather a crude one, but it is very useful when approximate and rapid results are required. So far as accurate determinations are concerned it is necessary to use the thermo-electric methods employed by Van Beek and Bergsma (10), Dutrochet (4), Stahl (7), Smith (6), Blackman and Matthaei (1), Miller and Saunders (5) and Culm (2). The method devised by them to measure the internal temperature of the leaves is sufficiently sensitive to record very minute fluctuations of temperature that may occur in the tendrils and it is possible by this method to detect any small change in the internal temperature of the tendril when it responds to a thigmotropic stimulus. The thermocouple was made by fusing copper and constantan wires. The D'Arsonoval galvanometer manufactured by Tinsley & Co., London, the resistance of the coil of which is 20 ohms, was used. The deflections of the galvanometer per rise or fall of unit degree Centigrade were about 5.5 to 6.0 cms. on the scale kept at a distance of one metre. The approximation given here is due to the fact that every time the couple breaks, it is necessary to standardise it as there will be a change in length on fusing the couple, and hence a change in deflection per unit degree on account of a change in resistance taking place. So it would be possible with the thermo-couple to measure the internal temperature of the tendril up to 1/100th of a degree in Centigrade. The external temperature of the air surrounding the tendril was also measured by Beckman's thermometer which could be read upto 1 100th of a degree in Centigrade. One of the couples is kept at a constant temperature in the Dewar's flask or thermos, properly corked, care being taken to see that the two wires do not make contact except at the junctions. The other couple is grounded properly and made thin and pointed in order that it might not injure the tissues of the tendrils. This couple is inserted in the tissues of the tendril carefully, so that no portion of the junction is exposed to the atmosphere. In order to minimise the error the readings were taken on both sides of the zero reading of the scale by reversing the current with commutator. By these means the temperature at both the bases and apices of curled, straight and stimulated tendrils were determined.

The results of the determinations of the internal temperature of straight and curled tendrils at the base and apex and when the apical sensitive portion of the tendril was stimulated by a gentle scratching, are given in the following tables. The temperature of the air is also given at the time of measurement. The difference between the internal temperature of the tendril and the temperature of the air are also given. This is necessary as the temperature of the air is fluctuating every moment and the internal temperature of the tendrils also correspondingly changes. Since the internal temperature of the tendrils is lower than the external temperature of the air, the differences are given with the minus signs. When the value of the difference between the internal temperature of the tendrils and the air temperature (I-A) is low, the internal temperature of the tendril (I) is relatively high. When the value of the difference between the two (I-A) is high, the internal temperature (I) of the tendril is relatively low.

Internal temperature of Luffa aegyptica, *Mill.*

Table III.

Straight tendril 32.1 cms.

	Apex				Base		
Time	Ext. temp. A	Int. temp. I	Diff. I-A	Time.	Ext. temp. A	Int. temp. I	Diff. I-A.
11-5	27.930	27.595	−0.335	12-5	27.65	26.982	−0.668
11-8	27.935	27.613	−0.322	12-7	27.67	27.036	−0.634
11-11	27.960	27.613	−0.347	12-9	27.70	27.054	−0.646
11-14	27.970	27.631	−0.339	12-11	27.72	27.072	−0.648
11-17	28.010	27.686	−0.324	12-13	27.74	27.145	−0.595
11-20	28.020	27.649	−0.371	12-15	27.74	27.145	−0.595
11-23	28.010	27.631	−0.379	...	...	...	...

Apex stimulated.				Curled tendril 33.3 cms. Apex.			
Time	Ext. temp. A	Int. temp. I	Diff. I-A	Time	Ext. temp. A	Int. temp. I	Diff. I-A
11-29	27.990	27.740	−0.250	4-21	29.07	28.521	−0.549
11-30	27.990	27.686	−0.304	4-23	29.08	28.557	−0.523
11-33	27.980	27.613	−0.367	4-25	29.10	28.503	−0.597
11-36	27.970	27.595	−0.375	4-28	29.12	28.595	−0.525
11-39	27.910	27.613	−0.297	4-31	29.11	28.485	−0.625
11-42	27.940	27.613	−0.327	4-33	29.11	28.503	−0.607
11-45	27.970	27.668	−0.302	4-35	29.10	28.503	−0.597
11-48	27.990	27.686	−0.304	4-37	29.11	28.467	−0.643

Table IV.

Straight tendril 30.2 cms.

Apex				Base			
3-4	28.39	27.868	−0.522	3-56	28.39	27.758	−0.632
3-6	28.33	27.813	−0.517	3-58	28.38	27.795	−0.585
3-8	28.31	27.777	−0.533	4-0	28.38	27.758	−0.622
3-10	28.29	27.704	−0.586	4-2	28.38	27.813	−0.567
3-12	28.28	27.865	−0.412	4-4	28.38	27.849	−0.531
3-14	28.30	27.813	−0.487	...	...	...	...
3-15	28.31	27.849	−0.461	...	...	...	...

Straight tendril Apex stimulated				Curled tendril 31.2 cms. Apex			
3-20	28.40	27.976	−0.424	11-45	28.76	28.099	−0.661
3-22	28.43	28.067	−0.363	11-47	28.76	28.099	−0.661
3-24	28.46	28.067	−0.393	11-49	28.76	28.044	−0.716
3-26	28.46	28.031	−0.429	11-50	28.76	28.044	−0.716
3-28	28.44	28.031	−0.409	11-54	28.77	28.153	−0.617
3-30	28.43	28.049	−0.381	11-56	28.76	28.099	−0.661
3-32	28.42	28.012	−0.408	11-58	28.76	28.099	−0.661
3-34	28.41	28.031	−0.379	12-0	28.73	28.062	−0.668

Table V.

Straight tendril 27.4 cms.

Apex				Base			
3-49	28.21	27.817	−0.393	4-40	28.17	27.635	−0.535
3-51	28.23	27.835	−0.395	4-42	28.16	27.708	−0.452
3-53	28.28	27.871	−0.409	4-44	27.91	27·326	−0.584
3-55	28.30	27.890	−0.410	4-46	27.80	27.163	−0.637
3-57	28.32	27.871	−0.449	4-48	27.71	27.145	−0.565
3-59	28.32	27.871	−0.449	4-50	27.69	27.236	−0.454
4-0	28.32	27.871	−0.449	...	...	...	...

Time	Ext. temp. A	Int. temp. I	Diff. I-A	Time	Ext. temp. A	Int. temp. I	Diff. I.A.
	Apex stimulated.				Curled tendril 27.1 cms. Apex		
4-4	28.30	27.926	−0.374	12-21	28.92	28.339	−0.581
4-6	28.31	27.890	−0.420	12-23	28.94	28.176	−0.764
4-8	28.31	27.871	−0.439	12-25	28.94	28.230	−0.710
4-10	28.32	27.853	−0.467	12-27	28.92	28.249	−0.671
4-12	28.30	27.799	−0.501	12-29	28.92	28.230	−0.690
4-14	28.30	27.817	−0.483	12-31	28.96	28.303	−0.657
4-16	28.30	27.780	−0.520	12-33	28.97	28.321	−0.649
4-18	28.24	27.780	−0.460	12-35	28.98	28.285	−0.695
4-20	28.24	27.780	−0.460	...	...	...	...

Table VI.

Straight tendril 14.1 cms.

	Apex				Base		
2-11	27.970	27.625	−0.335	3-8	28.08	27.453	−0.627
2-13	27.995	27.671	−0.324	3-10	28.07	27.435	−0.635
2-15	28.020	27.653	−0.367	3-12	28.06	27.435	−0.625
2-20	28.000	27.681	−0.319	3-14	28.06	27.435	−0.625
2-22	28.020	27.635	−0.385	3-15	28.06	27.435	−0.625
2-23	28.030	27.635	−0.395	...	...	...	...
2-25	28.020	27.617	−0.403	...	...	...	...
2-27	28.020	27.617	−0.403	...	...	...	...
2-29	28.030	27.635	−0.395	...	...	...	...
	Apex stimulated				Curled tendril 13.2 cms. Apex		
2-35	28.000	27.708	−0.292	2-31	29.11	28.467	−0.643
2-36	28.010	27.690	−0.320	2-33	29.11	28.485	−0.625
2-38	28.020	27.708	−0.312	2-35	29.08	28.430	−0.650
2-40	28.030	27.726	−0.304	2-36	29.08	28.467	−0.613
2-42	28.050	27.744	−0.306	2-39	29.07	28.412	−0.658
2-45	28.060	27.708	−0.352	2-41	29.07	28.394	−0.676
2-46	28.060	27.690	−0.370	2-43	29.07	28.430	−0.640
2-48	28.080	27.690	−0.390	2-44	29.07	28.394	−0.676
2-50	28.050	27.653	−0.397	...	...	...	...

Table VII.

Straight tendril 39.6 cms.

	Apex				Base		
11-49	27.75	27.254	−0.496	1-13	27.70	27.054	−0.646
11-51	27.75	27.199	−0.551	1-14	27.70	27.108	−0.592
11-53	27.65	27.127	−0.523	1-15	27.72	27.072	−0.648
11-55	27.50	26.816	−0.684	1-16	27.74	27.145	−0.595
11-57	27.46	26.781	−0.679	1-17	27.74	27.145	−0.595
12-1	27.34	26.745	−0.595	1-18	27.74	27.127	−0.613
12-3	27.33	26.872	−0.458	1-19	27.74	27.108	−0.458
12-5	27.35	26.818	−0.532	1-20	27.74	27.127	−0.613

	Apex stimulated				Curled tendril 37.3 cms. Apex		
Time	Ext. temp. A	Int. temp. I	Diff. I-A	Time	Ext. temp. A	Int. temp. I	Diff. I-A
12-10	27.36	26.854	−0.506	2-4	29.20	28.553	−0.647
12-12	27.37	26.927	−0.443	2-7	29.17	28.480	−0.690
12-14	27.40	26.818	−0.582	2-10	29.18	28.499	−0.681
12-16	27.39	26.836	−0.554	2-15	29.14	28.480	−0.660
12-18	27.39	26.909	−0.481	2-18	29.16	28.444	−0.716
12-28	27.57	27.108	−0.462	2-21	29.16	28.480	−0.680
12-30	27.60	27.199	−0.401	2-24	29.16	28.480	−0.680
12-32	27.62	27.62	−0.493	...	...	...	...

Internal temperature of Luffa acutangula, *Roxb.*

Table VIII.

Straight tendril 34.2 cms.

	Apex				Base		
3-23	28.05	27.811	−0.240	3-7	28.05	27.683	−0.367
3-25	28.07	27.883	−0.187	3-9	28.06	27.720	−0.340
3-27	28.07	27.901	−0.169	3-11	28.07	27.738	−0.332
3-28	28.06	27.920	−0.140	3-12	28.08	27.829	−0.251
3-29	28.08	27.956	−0.124	3-14	28.10	27.901	−0.199
3-31	28.09	27.956	−0.134	3-16	28.10	27.901	−0.199
3-33	28.09	27.938	−0.152	3-18	28.10	27.883	−0.217
	Apex stimulated			Curled tendril 37.1 cms. Apex			
3-35	28.05	27.974	−0.076	1-2	28.990	28.336	−0.654
3-37	28.06	27.956	−0.104	1-4	29.020	28.390	−0.630
3-39	28.08	28.010	−0.070	1-6	29.025	28.427	−0.598
3-41	28.08	27.956	−0.124	1-8	29.055	28.481	−0.574
3-43	28.08	27.920	−0.160	1-12	29.090	28.499	−0.591
3-45	28.05	27.920	−0.130	1-14	29.100	28.517	−0.583
3-47	28.07	28.010	−0.060	1-16	29.130	28.499	−0.631
3-49	28.09	28.010	−0.080	1-18	29.160	28.572	−0.588

Table IX.

Straight tendril 29.8 cms.

	Apex.				Base		
2-20	27.02	26.688	−0.332	2-10	26.99	26.319	−0.671
2-22	27.04	26.724	−0.316	2-12	26.96	26.429	−0.531
2-24	27.08	26.778	−0.302	2-15	26.98	26.429	−0.551
2-25	27.31	26.908	−0.402	2-17	26.98	26.429	−0.551
2-27	27.33	26.926	−0.404	2-19	26.99	26.429	−0.561
2-29	27.36	26.944	−0.416	...	...	...	...

Time	Ext. temp. A	Int. temp. I	Diff. I-A	Time	Ext. temp. A	Int. temp. I	Diff. I-A
	Apex stimulated			Curled tendril 29.9 cms. Apex			
2-33	27.32	27.106	−0.214	11-50	28.92	28.172	−0.748
2-35	27.32	27.086	−0.232	11-52	28.93	28.209	−0.721
2-37	27.33	26.998	−0.332	11-54	28.93	28.172	−0.748
2-39	27.35	26.980	−0.370	11-57	28.96	28.281	−0.679
2-40	27.39	26.944	−0.446	12-2	28.98	28.336	−0.644
2-42	27.39	26.962	−0.428	12-4	28.98	28.336	−0.644
2-44	27.40	26.998	−0.402	12-6	28.97	28.245	−0.725
2-46	27.44	26.998	−0.442	12-8	28.97	28.281	−0.689

Table X.

Straight tendril 28.2 cms.

	Apex				Base		
11-11	27.76	27.361	−0.399	11-0	27.80	26.907	−0.893
11-13	27.78	27.434	−0.346	11-2	27.80	26.925	−0.875
11-14	27.78	27.434	−0.346	11-4	27.81	26.925	−0.885
11-15	27.80	27.470	−0.330	11-6	27-81	26.925	−0.885
11-17	27.81	27.489	−0.321	...	...	...	...
11-19	27.82	27.507	−0.313	...	...	...	...
11-21	27.83	27.543	−0.287	...	...	...	...
	Apex stimulated			Curled tendril 26.6 cms. Apex			
11-25	27.81	27.507	−0.303	4-30	29.47	28.972	−0.498
11-27	27.81	27.525	−0.285	4-32	29.47	28.972	−0.498
11-29	27.81	27.543	−0.267	4-34	29.41	28.954	−0.456
11-30	27.82	27.507	−0.313	4-36	29.41	28.936	−0.474
11-31	27.88	27.561	−0.319	4-38	29.42	28.881	−0.539
11-33	27.88	27.525	−0.355	4-40	29.43	28.936	−0.494
11-35	27.88	27.507	−0.373	4-44	29.45	28.936	−0.494

Table XI.

	Apex			Straight tendril 19.4 cms. Base			
5-40	27.92	27.673	−0.247	4-22	28.22	27.764	−0.456
5-42	27.92	27.728	−0.192	4-24	28.22	27.746	−0.474
5-44	27.92	27.755	−0.165	4-25	28.22	27.800	−0.420
5-46	27.94	27.782	−0.158	4-26	28.22	27.764	−0.456
5-48	27.94	27.782	−0.158	4-28	28.23	27.764	−0.466
5-50	27.94	27.728	−0.212	4-30	28.25	27.800	−0.450
...	...	...	...	4-32	28.25	27.764	−0.486
	Apex stimulated			Curled tendril 17.4 cms. Apex			
5-55	27.96	27.858	−0.102	4-50	29.410	28.790	−0.620
5-57	27.96	27.728	−0.232	4-52	29.400	28.754	−0.646
5-59	27.97	27.746	−0.224	4-54	29.380	28.717	−0.663
6-1	27.99	27.801	−0.189	4-56	29.380	28.717	−0.663
6-3	27.99	27.800	−0.190	4-58	29.375	28.699	−0.676
6-5	28.00	27.800	−0.200	5-0	29.390	28.790	−0.600
6-7	28.00	27.819	−0.181	...	...	...	...

At first, the internal temperature of an unstimulated tendril was measured for a certain length of time. Then the tendril was stimulated by gentle scratching on the sensitive side and the internal temperature recorded. The results of the two measurements are given in the foregoing tables. In some cases as in Luffa acutangula, Roxb., there is a little rise in the internal temperature of the tendril after stimulation as could be seen from the fall in difference from 0.124 to 0.060 in the table VIII or 0.416 to 0.214 in the table IX. But the fall in the value I-A disappears after a couple of minutes. In some cases as in Luffa aegyptica, Mill., no such fall in the difference (I-A) is observed. The small fluctuations in the internal temperature after stimulation may be due to the effect of heating produced by scratching and the rise in temperature in some cases may be attributed to it, as the rise in temperature is not maintained even for 3 minutes. The internal temperature of the tendril does not show any rise even when a coil at the apex is being formed as a result of stimulation.

This investigation has brought to light the necessity of measuring very accurately the external temperature of the air when the internal temperature of the plant organ is to be measured. As the external temperature varies to the extent of 1 100th of a degree Centigrade, there is a change in the internal temperature. This change in the internal temperature may be wrongly attributed to internal causes in the absence of corresponding observations of the air temperature of the same degree of fineness.

In both the species of Luffa the internal temperature of the straight tendrils near the base is lower than the internal temperature of the tendrils near the apex. In Luffa aegyptica, Mill., the difference between the internal and the external temperature at the base varies between 0.5 to 0.6 of a degree, while at the apex the difference between the internal and external temperature varies between 0.3 to 0.4 of a degree, indicating that the base is at a lower temperature than the apex. The following table gives the difference I-A at the apex and the base.

Table XII.

	Length.	I-A at the apex.	I-A at the base.
Luffa aegyptica, Mill.	32.1 cms.	0.3 – 0.4	0.5 – 0.6
	30.2 „	0.4 – 0.5	0.5 – 0.6
Luffa acutangula, Roxb.	29.8 „	0.2 – 0.4	0.8
	34.2 „	0.1 – 0.2	0.2 – 0.35

The internal temperature of the straight tendrils of approximately the same lengths are different.

It is also apparent that the internal temperature of the curled tendrils is lower than the internal temperature of the straight tendrils. The following table gives the results showing the differences :—

Table XIII.

	Lengths	I-A of St. T.	I-A of curled T.
Luffa aegyptica, Mill.	32.1 cms.	0.30–0.40	0.50–0.65
	30.2 "	0.40–0.50	0.56–0.70
	21.4 "	0.28–0.45	0.80–0.90
	14.1 "	0.30–0.40	0.57–0.67
	39.7 "	0.50–0.70	0.50–0.70
Luffa acutangula, Roxb.	34.2 "	0.10–0.25	0.60–0.70
	29.8 "	0.20–0.40	0.67–0.78
	28.2 "	0.28–0.40	0.45–0.55
	19.4 "	0.10–0.24	0.50–0.67

In some cases there is a greater difference between the internal temperatures of straight and curled tendrils of the same age of a species. This may be due to the curled tendril being in the curled position for a longer period. If the curling has occurred lately when the measurement of temperature is made, the temperature would be higher than in the tendril which had curled round a support at an earlier period.

Determination of the water contents of the tendrils of Cucurbitaceae at different stages of growth.

The water contents of the straight tendrils in different stages of growth were determined by the ordinary method of noting the difference in their fresh and dry weights. The water contents of the tendrils in the same stage of growth may vary according to the position on the plants and the distance from the apex, so the position of the tendril whether on main or lateral branch and the number of nodes from the base or apex (not given in the tables) are first noted. The length of the tendril is then determined. It is cut at the base from the plant, placed in a long narrow glass tube, sealed at one end and tightly corked at the other, and weighed. The dry weight of the tendril is then determined after drying it for 24 hours at 110°C. The dry weight of the tendril is extremely small and great care is needed in the process of drying and weighing. The water content is then reduced to unit length and also to unit dry weight.

Table XIV.
Water contents of the straight tendrils of

Coccinia indica, W. & A.			Citrullus vulgaris, Schrad.			Momordica Charantia, L.		
L. in cms.	W. C. per unit L. in m. gms.	W. C. per unit D. Wt. in m. gms.	L. in cms.	W. C. per unit L. in m. gms.	W. C per unit D. Wt. in m. gms.	L. in cms.	W. C. per unit L. in m. gms.	W. C. per unit D. Wt. in m gms.
2.3	1.6	5.4	1.9	2.1	5.6	6.9	3.4	5.8
3.0	1.6	6.1	2.6	3.5	5.1	8.9	3.1	5.8
3.7	1.7	6.3	3.6	3.6	6.1	9.6	3.2	6.0
4.2	1.6	6.7	3.8	4.3	6.8	9.8	3.4	5.8
4.3	1.7	6.5	4.4	4.3	7.0	10.0	3.9	5.8
5.0	2.2	6.2	4.6	5.4	7.1	10.4	3.7	6.2
5.5	2.2	7.4	4.9	4.8	7.3	11.5	4.0	6.2
5.6	2.7	8.0	5.6	5.3	7.6	11.6	4.2	6.5
5.7	2.8	8.5	6.0	6.1	7.8	12.6	4.6	7.0
7.0	3.3	9.7	8.3	6.0	8.3	14.6	4.0	7.3
7.3	3.5	9.8	10.7	5.8	8.0	15.4	4.5	7.4
9.0	3.6	10.2	11.0	5.9	8.2	16.1	4.5	7.0
10.1	4.0	11.8	11.3	6.1	8.2	16.8	4.9	7.3
...	...	...	13.6	6.6	8.3	17.6	5.5	7.4
...	...	...	19.2	8.8	9.4	...	...	...
...	...	...	23.7	15.3	12.4	...	...	...

Table XV.
Water contents of the straight tendrils of

Cucumis sativus, L. (Chibud).			Cucumis sativus, L. (Cucumber).			Luffa acutangula, Roxb.		
2.6	0.8	3.5	8.3	3.0	4.3	1.7	0.6	2.7
2.9	1.5	5.0	11.0	10.1	6.4	2.0	1.0	5.0
4.1	2.6	6.6	11.3	8.5	5.7	2.0	1.4	5.8
6.2	2.6	6.5	11.4	5.3	8.0	2.6	2.3	5.6
6.3	2.9	6.6	12.2	10.8	7.0	2.7	2.0	7.0
6.6	2.7	7.6	15.5	10.3	9.4	3.0	2.0	6.9
7.4	2.3	7.6	17.6	13.3	8.6	3.1	2.4	6.2
7.5	4.1	7.0	18.6	4.9	4.2	3.3	2.4	7.2
8.8	4.7	6.1	19.7	14.8	10.0	4.1	2.3	7.4
9.1	4.9	7.2	20.2	14.7	10.9	4.1	2.5	7.3
10.4	4.5	6.8	21.2	18.9	12.4	6.0	2.9	7.4
12.1	5.8	6.8	23.8	17.7	13.1	6.4	3.3	7.0
13.7	5.7	7.2	26.6	14.3	9.2	6.8	2.1	7.3
16.4	6.2	7.5	27.5	14.9	11.0	7.7	3.8	8.1
16.5	6.9	7.7	34.2	23.8	28.8	9.2	4.0	8.2
19.6	6.6	7.9	34.6	22.7	24.6	9.4	4.2	9.3
21.2	7.3	8.2	...	...	...	9.9	4.7	9.3
...	...	...	...	...	...	20.5	7.6	9.9

Table XVI.
Water contents of the straight tendrils of

Cucurbita maxima, Duch.			Benicasa cerifera, Savi.		
1.6	1.8	2.9	4.9	6.9	8.4
3.3	2.9	4.7	6.0	7.6	9.7
3.5	4.5	6.1	8.4	6.7	10.6
4.2	5.1	6.0	9.7	10.4	11.4
4.8	4.6	5.4	14.2	11.2	10.6
5.2	5.0	5.4	15.4	8.0	10.7
6.3	6.2	5.8	15.8	15.4	11.2
6.3	6.9	7.0	17.7	14.2	11.3
6.7	7.3	8.6	22.7	12.4	10.3
9.6	9.5	9.1	27.1	11.2	10.3
10.1	6.3	7.1	27.1	17.2	11.1
10.5	10.0	8.1	31.4	22.5	13.1
12.2	12.4	8.0	...	...	...
13.0	5.5	7.5	...	...	...
13.5	6.4	8.2	...	...	...
16.2	10.9	8.5	...	...	...
17.2	10.7	10.0	...	...	...
23.5	16.1	11.5	...	...	...
27.2	18.2	9.6	...	...	...
27.5	13.6	10.5	...	...	...

On studying the figures in the above tables XIV to XVI it is clear that the water contents of the tendrils in all the species of Cucurbitaceae examined increase as the lengths of the tendrils increase and in fully grown tendrils the water contents reach their highest value. The water contents of the tendrils increase both per unit lengths and per unit dry weights.

Determination of the Suction Pressure of the Tendrils.

As discussed above in the introduction, the measurement of the suction pressure of the tendrils in straight and curled conditions could yield results of interest and was subsequently undertaken. The new method devised by Ursprung and Blum (9) which can be used both in the laboratory as well as in the field is employed here in determining the suction pressure of the tendrils. In this method a whole strip of tissue is used in measurement, instead of a single cell, so that we obtain the average suction pressure of the whole strip of tissue.

According to the results the suction pressure of a tendril rises from the base towards the apex, so that the suction pressure is lower at the base, higher in the middle portion and highest at apex.

Table XVII.

The suction pressure of Cucumis sativus, L. (Chibud)						The suction pressure of Cucumis sativus, L. (Cucumber)					
Straight tendrils.			Curled tendrils.			Straight tendrils.			Curled tendrils.		
Length in cms.	S. P. at base in atms.	S. P. at apex in atms.	Length in cms.	S. P. at base in atms.	S. P. at apex in atms.	Length in cms.	S. P. at base in atms.	S. P. at apex in atms.	Length in cms.	S. P. at base in atms.	S. P. at apex in atms.
5.5	2.45	3.6	...	...	...	8.1	4.9	7.50	...	...	...
6.8	3.60	4.9	6.8	1.30	3.1	13.5	4.9	7.50	13.5	3.7	6.5
7.5	4.90	6.5	7.5	1.30	3.6	14.6	4.9	7.50	14.5	3.4	6.5
7.8	3.60	4.9	8.5	1.90	3.6	18.5	4.4	8.05	17.1	4.0	6.5
9.2	4.90	6.5	...	...	...	19.8	5.5	7.50	19.0	3.1	5.6
9.9	4.90	6.5	9.9	2.45	4.9	22.8	4.2	8.80	22.5	3.7	6.5
10.9	5.60	7.5	11.3	2.45	5.6	...	...	...	...	...	...
11.5	5.60	8.8	11.5	2.45	6.5	...	...	...	...	...	...

Table XVIII.

The Suction Pressure of Cucurbita maxima, Duch.						The Suction Pressure of Benicasa Cerifera, Savi.					
Straight tendrils.			Curled tendrils.			Straight tendrils.			Curled tendrils.		
8.8	4.4	7.50	8.5	2.5	4.9	11.7	4.9	8.1	...	...	...
12.5	3.1	6.50	17.5	3.1	4.9	13.1	6.3	8.8	13.9	3.6	6.9
21.5	4.9	8.05	22.3	3.1	5.6	13.4	6.3	8.8	16.1	3.6	6.9
24.3	3.7	7.50	22.8	3.1	5.6	15.1	6.3	9.0	16.4	4.9	8.8
26.5	3.7	7.50	28.2	3.7	6.5	19.6	6.3	8.8	...	...	...
34.5	4.4	7.50	36.3	3.7	6.5	23.0	7.5	11.5	23.4	5.6	9.6
35.3	4.4	8.80	42.7	3.2	7.0	31.7	8.1	12.5	33.2	6.3	10.1

Table XIX.

The suction pressure of Coccinia indica, W. & A.						The suction pressure of Momordica Charantia, L.					
Straight tendrils.			Curled tendrils.			Straight tendrils.			Curled tendrils.		
Length in cms.	S. P. at base in atms.	S. P. at apex in atms.	Length in cms.	S. P. at base in atms.	S. P. at apex in atms.	Length in cms.	S. P. at base in atms.	S. P. at apex in atms.	Length in cms.	S. P. at base in atms.	S. P. at apex in atms.
7.7	4.95	8.20	8.9	4.40	7.1	10.6	3.1	4.9	9.5	2.8	4.4
10.4	6.35	8.80	11.4	4.95	7.1	11.4	3.1	5.6	10.2	2.5	4.4
14.2	6.25	9.6	14.8	4.95	7.5	12.5	3.1	4.9	14.2	3.1	4.5
15.9	7.00	10.25	14.9	4.40	7.5	16.8	3.7	6.9	17.1	3.7	4.9
18.2	7.20	10.25	17.0	5.60	8.2	19.5	4.9	6.8	18.0	3.7	4.9
21.2	6.25	10.30	19.5	5.60	8.8	20.1	4.9	6.5	20.3	3.7	4.9

Table XX.

The suction pressure of Luffa acutangula, Roxb.						The suction pressure of Trichosanthes Anguina, L.					
Straight tendrils.			Curled tendrils.			Straight tendrils.			Curled tendrils.		
5.0	3.20	5.6	4.8	1.9	3.7	3.8	2.45	5.6	5.3	1.90	4.2
9.0	3.70	6.5	7.5	1.9	3.7	4.5	2.45	5.6	6.1	1.90	4.4
9.2	3.70	6.5	9.6	2.5	5.2	5.4	2.45	5.6	8.9	3.10	5.6
11.0	3.70	6.5	10.7	2.5	5.6	8.5	3.75	7.6	9.5	3.10	5.8
12.0	3.95	6.8	13.2	2.5	4.9	9.0	4.30	7.6	10.8	3.75	6.1
15.9	3.10	7.5	14.0	3.7	5.6	9.7	4.30	7.6	11.5	3.00	5.0
22.0	3.70	7.5	24.8	2.5	5.6	14.2	5.00	8.8	16.1	3.75	7.6
...	...	...	32.3	3.7	6.5	...	...	...	...	...	...

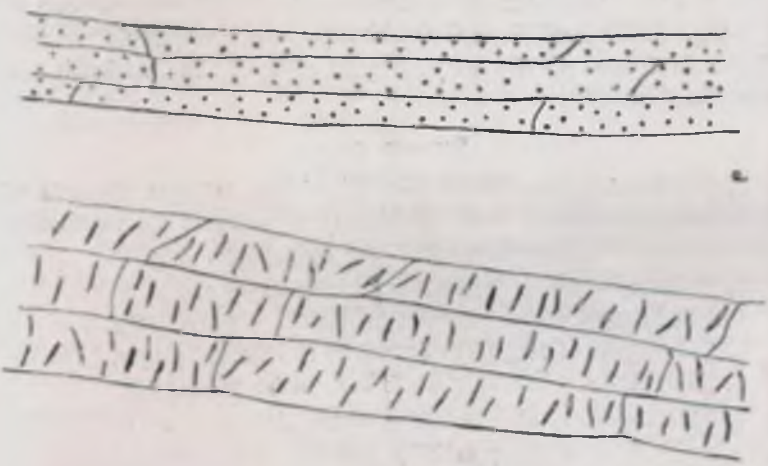
As seen from the results the suction pressure at the base or at the apex increases as the tendrils grow in length. The increase in the suction pressure is greater at the apex as the age advances. The suction pressure in the tendrils of Cucumis sativus, L. (variety Chibud) is 3.6 atms. at the apex of the young tendril, 5.5 cms. long, while it has increased to 8.8 atms. in a tendril 11 cms. long. At the base of the tendril of the same species it has risen from 2.45 atms. to 5.6 atms. In curled tendrils, however, the same rise in suction pressure at the base and apex is not observed with the advance of age.

The most interesting feature of this measurement is the difference in the suction pressure between the straight and curled tendrils of nearly the same age. The suction pressure in a straight tendril is higher than the suction pressure in a curled tendril of the same length.

Conclusions.

The results of the measurements of suction pressure favour the physical view of the mechanism of curvature of tendrils, as there is a distinct fall in the suction pressure in the curled tendrils. The measurements of the respiratory activity and of the internal temperatures of the tendrils do not go to support the physiological view of the mechanism of curvature of tendrils. So the physiological evidence is not contradictory to the physical view and it supports the conclusions reached by Dastur and Kapadia (3) for the curvature of tendrils in Cucurbitaceae. The measurement of the water contents of the tendrils show that the water content per unit length and per unit dry weight increases as the tendril grows, indicating that the tendril becomes more and more turgid as they mature and it is due to the turgescence of the cells that the tendrils are able to remain horizontal without drooping. This would not be the case if they are not turgid, as there is no other mechanical tissue developed in uncurled and straight tendrils. The whole tendril is in a state of tension, as the arrangement, size and nature of cells on the concave and convex sides of these bilateral tendrils are such that one side would elongate more than the other, if the state of tension is relieved. This is clearly supported by the fact that at the tip the tendril is slightly curled in the same direction, and once the tension falls by contact with a support, the tendrils would elongate, and the physical elongation of the cells on the two sides of the tendril would take place according to the nature of the elements. The cells on the concave side are small and narrow whilst those situated on the convex side are large and broad. So this side (convex side) elongates more than the other (concave side) and the curvature results. The curvature extends backwards and the free portions of the tendrils are thrown into spirals for the same reasons.

The anatomical features of the tendrils of Cucurbitaceae are described by Dastur and Kapadia (3) and they have put forward that the physical elongation of the parenchymatous cells of the convex side brings about the curvature of the tendrils. They have not produced any evidence in support of the view put forward by them that the elongation of cells takes place by the passage of water into these cells through the vessels.



Longitudinal section of a tendril of Luffa aegyptica, *Mill.*
(*a*) Cells with round pits on the concave side.
(*b*) Cells with transversely elongated pits on the convex side.

While investigating the anatomy of the tendrils, two facts unnoticed before came to light. The cells which undergo physical elongation on the convex side are provided with numerous transverse pits on the surface of their walls. The cells are pentagonal or hexagonal in transverse section and the cell-walls are thick at the angles, but very thin over the whole surface. In the surface region are found numerous pits mentioned above (Fig. 1b). The pits are transversely elongated and appear like slits in the walls. They could be seen in an unstained section and after trying various reagents and stains, it was discovered that they are made more conspicuous when they are stained with Chlorozinc Iodine. The pits are visible in the longitudinal as well as obliquely transverse sections. The cortical cells on the concave side also show simple minute pits, but they are small and round and not transversely elongated (Fig. 1a). Secondly the cells on the convex side are in uninterrupted contact with one another and there are no intercellular spaces between them.

It has been put forward by Dastur and Kapadia (3) that when a tendril rubs against an uneven surface, the fall in tension in the straight tendril occurs and this fall in tension is probably followed by the escape of water from the conducting elements into the cells which undergo elongation. The presence of pits in the cell-walls of the elongating cells on the convex and concave sides gives support to the above view.

It is clear from the observations made in different aspects of physiology of the tendrils of Cucurbitaceae, that there is no punitive evidence in favour of the physiological view of the mechanism of curvature of tendrils.

Summary.

The following aspects of the Physiology of the Tendrils of Cucurbitaceae were studied with a view to understand the mechanism of curvature of tendrils when stimulated by contact.

1. The respiration of tendrils at different stages.
2. The internal temperature of tendrils at different stages.
3. The degree of turgidity of tendrils at different stages.
4. The suction pressure of tendrils at different stages.

1. Measurements of respiration show that the curled tendrils have very little respiratory activity in comparison to straight tendrils. There is no increased output of CO_2 when the tendrils curl. As the age advances respiration decreases.

2. The internal temperature of the tendrils also support the view that very little energy is given out when the tendril is stimulated to curl, i.e., there is no rise of temperature on stimulation. The results show that the temperature in the plant organs is lower than that of the atmosphere. The temperature at the base is lower than that at the apex. In a curled tendril it is lower than that in the straight tendril of corresponding length. Internal temperatures of the straight tendrils of the same lengths are different. Two curled tendrils of the same lengths can have different temperatures owing to the difference in the age of curling. The temperatures of the stimulated tendrils fluctuate, but the fluctuations are of the same degree before and after stimulation.

3. The degree of turgidity of tendrils is determined by determining the water contents of the tendrils per unit length and per unit dry weight. The results show that as the age of the tendril advances the water content increases both per unit length and per unit dry weight in all the species of Cucurbitaceæ examined, and that in the fully grown tendril the water content reaches the highest value.

4. The suction pressure of the tendrils of Cucurbitaceæ increase with length in case of straight tendrils. The suction at the apex is higher than at the base in all the species examined. The suction pressure in the straight tendrils is higher than that in the curled tendrils of corresponding lengths.

The results obtained from the study of the above-mentioned aspects of the Physiology of the tendrils do not support the physiological view of the mechanism of curvature of tendrils.

The discovery of small pits in the cells which according to Dastur and Kapadia (3) undergo physical elongation when curvature takes place, supports the physical view expressed by them for the mechanism of curvature of tendrils in Cucurbitaceæ.

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