Distribution and Quantity of Starch Granules in Sugarcane Tissues

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Although the starch granules stored in the sugarcane are useful as a food for its germination and growth, from the view point of sugar refining process it is recognized that the smaller the starch contents are the more preferable are they on account of the lowering filterability of raw sugar and the quality of the refined sugar [3) 5)]. Some works, therefore, have been done on the variation of starch contents among different varieties as well as on the starch distribution in the cane organs [2) 4)]. But the former researches were mainly based on the chemical analyses of large combined tissues, and the latter seems to be made only on the limited tissues.

For this reason, the present report aimed to clear starch distributions in tissues of broader regions of the cane plant and, at the same time, to ascertain whether those differences on starch contents could be detected or not by the microscopic observation of the tissue-sections.

Materials and Methods

The materials used were two principal cane varieties, F 146 and N : Co 310, and a wild type, Glagah, starch contents of which being evidently in the following order, F 146 〈N : Co 310〈 Glagah. All the tissues for the observation were taken from the plants grown in the laboratory field during August-November, N : Co 310 in 1968-70 and other two in 1970; and they were immediately stored after in FAA solution. Microscopic observations of the starch granules were made on the sections of the tissues, cut with the lazor and dyed with IIK solution. The grains in a tissue were variable in size and hence those appearing to be representative were measured to indicate the grain size in each tissue.

Results and Discussion

Distributions and relative amounts of starch granules in each tissues of the different organs of F 146, N : Co 310 and Glagah are summarized in Table 1 and microscopic observations on the several important tissues are presented in 10 figures.

As shown in Figure 1, the starch granules near the shoot apices were most abundant both at the young stems and basis of the leaves, varying in quantity between varieties, and size of granules were about 3.2 μ diameter in the former parts and 1.6 μ diameter in the latter, but few both in the spike primordia and leaves. The granules of Glagah appeared to be somewhat bigger than that of other two varieties.

At the mid-portion of 5-7 th internodes, as seen in Figure 2, small starch granules of 1.6 μ diameter were found in the parenchyma, especially in peripheral regions, though somewhat greater amounts of granules of 3.2 μ diameter were presented in 1-2 layers of cells adjacent to the vascular bundles mainly at the xylem sides. The comparative amounts of starch granules were in the following order, F 146 〈N : Co 310〈 Glagah and the difference between the former two were greater than that between the latter two.

In 8 th internode, the upper portions showed nearly similar distributions as that mentioned above. On the other hand, at the middle and bottom portions, there were some trends in the parenchyma excepting the peripheral parts to concentrate the starch distributions mainly to 1-2 layers of cells surrounding the vascular bundles especially in two commercial varieties, where the varietal differences on the grain diameter were found, viz., 4.8 μ in Glagah, 3.2 μ in N : Co 310 and 3.2-2.1 μ in F 146. It was apparent that the concentrations of starch in these sections decreased gradually from the upper portions towards the lower portions of the stem in proportion to ripening progress.

Figure 3 shows the distributions of starch granules at the lower portions of the internodes of the millable stems. In this parts, the trend of the concentration of starch granules into 1-2 cell layers surrounding the vascular bundles were remarkable, and granules were disappeared perfectly from other parts of the parenchyma in two varieties but not in Glagah, which seemed to be the most peculiar characteristic for the distinguishing commercial varieties or probably *Saccharum officinarum* from Glagah or probably wild canes. In this respect, the observation should be broaden on many other Saccharum species. At the same time, size of starch grains also should be examined, as that of Glagah was approximately doubled that of F 146 as well as N : Co 310 not only in this stem parts but also in leaf sheaths as mentioned below. It was detected that starch was accumulated most abundantly at the intercalary meristem in a internode.

In the leaf blades, starch granules were mostly limited to bottom portions, especially leaf joints, where 1-2 large amounts of granules were contained in 1-2 parenchyma cell layers adjacent to the vascular bundles and few granules were scattered in other parts of the parenchyma, besides the starch was distinctly decreased from central part towards outer side (Figure 4. 5.). Very small grains, looked like starch grains but dyed with IIK solution in violet color, were presented in the bundle-sheath cells of almost all portions of the blades, but they seemed to be true starch described in 'Sugarcane physiology'[1].

Although some starch granules were scattered in the parenchyma cells both in the upper and middle portions of the leaf sheath, the main location of starch was the parenchymatous cells most adjacent to the vascular bundles as similar as the blade (see Figure 6). In both blades and sheaths, the quantity of granules were in the following order, F 146 〈N : Co 310〈 Glagah, and also grain size were similar to that in the internodes of the ripened stems, though that of Glagah appeared to be somewhat bigger in the sheath than that in the blade.

Figure 7 shows the distribution of the starch granules in a bud attached on the lower portions of the stem of N : Co 310. In all varieties, granules were contained in almost whole parencyma cells of inner scales and were 1.6 μ in diameter in 1-2 th scales, while 3.2 μ in two varieties and 4.2 μ in Glagah in other scales. In the scales at outer-side, starch was confined in the cells adjacent to the vascular bundles, and outermost hard scales contained no granule. These aspects were also found in the

small buds on the upper nodes but the starch contents were generally larger in the young buds than in the big buds and besides, they varied among the varieties in the latter buds but not in the former.

At the root tips of the elongating roots, the starch granules were, as seen in Figure 8, presented in the root caps; almost all of the cap cells contained much granules in Glagah, while outer-side-regions lacked them in F 146 and N : Co 310, it happened in the broader range in the former than in the latter. Very small quantities of starch granules were rarely found at the cortex and central cylinder near growing point. Granules in the cells very near the growing point were quite small in size, and on the other hand, those in other cells were bigger, 4.8 μ in Glagah and N : Co 310 and 3.2 μ in F 146. Relative amounts of the starch granules per cell at the root tips appeared to be the largest through all the tissues examined, and the granules occupied over half volume of a cell, approximately seven teenth in the extreme case, showing the tendency of gathering around the nucleus. It was detected that the starch granules vanished from the very old root tips.

There are many root-primordia at the root-bands of the cane stem. Figure 9 presents the distributions of starch granules in the small root primordia at the root band of the upper portions of the stems. Comparatively small quantities of granules exist in the cap-cells at the inner-side-regions of the root-caps.

Only in Glagah, grains were found also at the parenchyma around the base of the primodia. Starch distributions in a relatively developed root-primordium on the millable stem of N : Co 310 are presented in Figure 10. As the Figure shows, much starch granules were found in the root-cap as well as in the parenchyma of the base regions.

It is concluded that starch granules were stored in the parenchyma of all organs; granules are distributed in almost whole parenchyma in young vial tissues and are limited, in old tissues, in 1–2 layers of parenchyma-cells surrounding vascular bundles in the commercial varieties.

Wild cane, Glagah, were distinctly differed from the commercial varieties in the fact that starch granules were contained in almost whole parenchyma cells even in the ripe stem and were relatively large in size. It should be worth mentioning that as the difference of the characteristic starch contents between the varieties could be detected by the microscopic observations of the tissue-sections of almost all kinds of organs, the method will be helpful for the breeding of low-starch-content varieties.

Summary

Microscopic observations were made with free hand sections of the tissues of several kinds of organs of the sugar cane. The materials were commercial varieties, F 146 and N : Co 310, and wild cane, Glagah, which were evidently different in starch contents in the order, F 146 〈N : Co 310〈 Glagah.

As to the characteristic difference of starch contents, the results of the observation indicated clearly that they could be detected by the microscopic observations of tissue-sections in many kinds of organs.

There were two types of starch distributions in a tissue; one is the type in which starch granules distribute in whole parenchyma-cell, mainly in young tissues, and another is the type in which granules are limited in 1–2 cells surrounding the vascular

bundles in the old tissues.

The most distinct difference between Glagah and commercial varieties was the fact that the former stored starch in the whole parenchyma-cells even in ripe stems, but the latter was otherwise. Generally, starch granules of Glagah were uniformed and larger than those of commercial varieties, and that of F 146 was somewhat smaller than that of N : Co 310, though the difference was not so clear in some tissues.

Table 1. Distribution of starch granules in several sugar cane tissues by the microscopic observation on two commercial varieties, F 146 and N : Co 310, and a wild cane, Glagah, different mutually in starch contents.

Tissue	F 146	N : Co 310	Glagah
Near shoot apex			
Flower primodium and leaf	+	+	+
Stem part and leaf base	++	+++	+++
Internode			
Top portion of stem (5–12 th)			
1–2 parenchyma cell layers surrounding vascular bundle	++	+++	+++
Other parenchyma	+	++	+++
Millable portion			
1–2 parenchyma cell layers surrounding vascular bundle	++	+++	+++
Other parenchyma	−	−	+++
Leaf blade			
Upper and mid portion			
Parenchyma	−	−	−
Lower portion			
1–2 parenchyma cell layers surrounding vascular bundle	+	++	+++
Other parenchyma	−	−	−
Leaf sheath			
1–2 parenchyma cell layers surrounding vascular bundle	+	++	+++
Other parenchyma	−	−	−
Bud on immature stem			
Outer scale	++	++	+++
Inner scale	+++	+++	+++
Bud on ripe stem			
Outermost scale	−	−	−
Outer scale	+	+	++
Inner scale	++	+++	+++
Root cap			
Elongating root tip	++	+++	++++
Root primordia at root band	+	+	++

References

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Explanation of Figures

Figures show the distribution of starch granules with black dots in the tissues of commercial sugarcane varieties F 146 and N : CO 310 and wild cane, Glagah.

Figure 1. Median longitudinal sections of shoot apices with spindle leaves, flower primordia and subjacent stem parts (x 15).
2. Transections of internode at the top portions of stems (x 28).
3. Transections of lower portions of millable stalk internodes (x 28).
4. Transections of inner parts of lower portions of leaf blades (x 92).
5. Transections through around midribs of the lower portions of leaf blades (x 50).
6. Transections of inner parts of the lower portions of leaf sheaths (x 70).
7. Transection of a bud at a millable stalk node of N : CO 310 with scale numbers (x 28).
8. Median longitudinal sections of root tips (x 50).
9. Longitudinal sections through small root primordia of root bands at the rest stage. (x 50).
10. Median longitudinal section of large root primordium of a root band of N : CO 310 at the initial elongation stage (x 52).

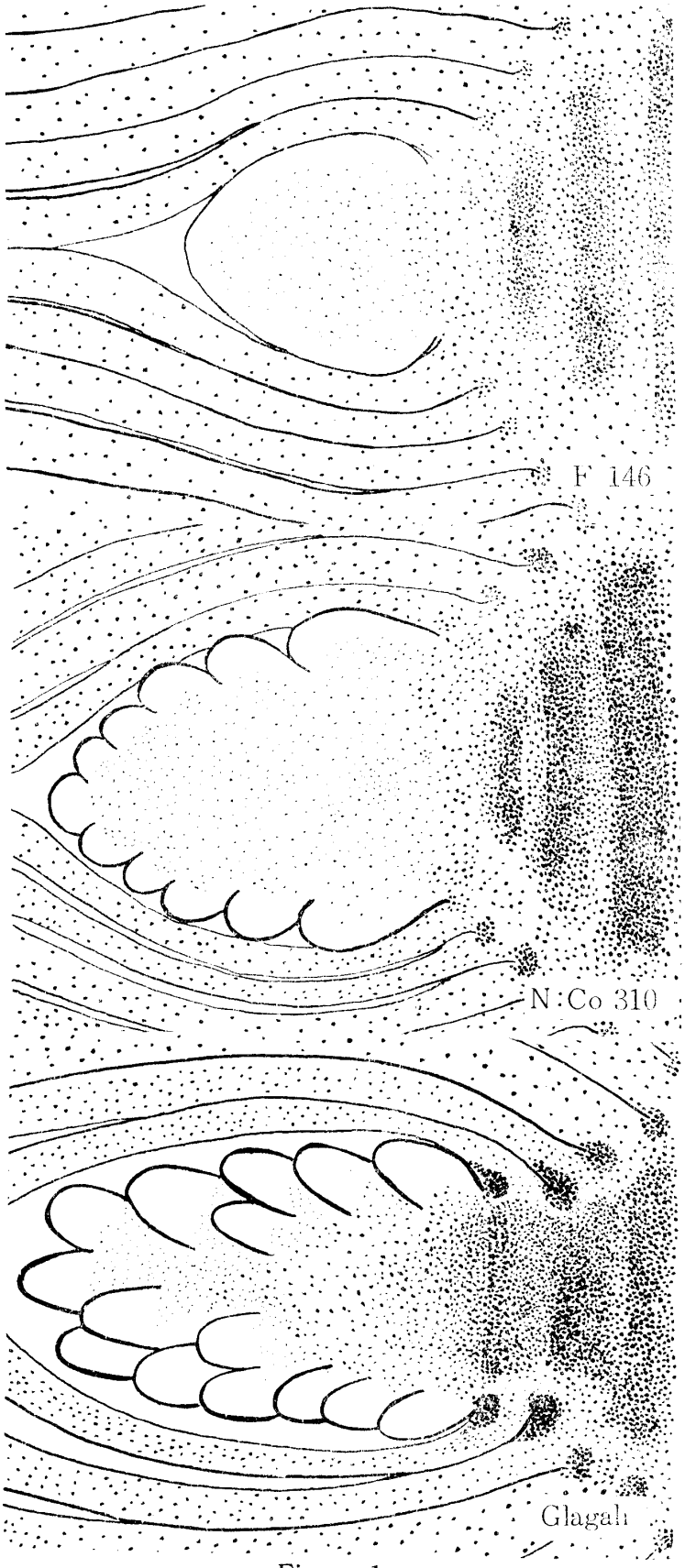

Figure 1.

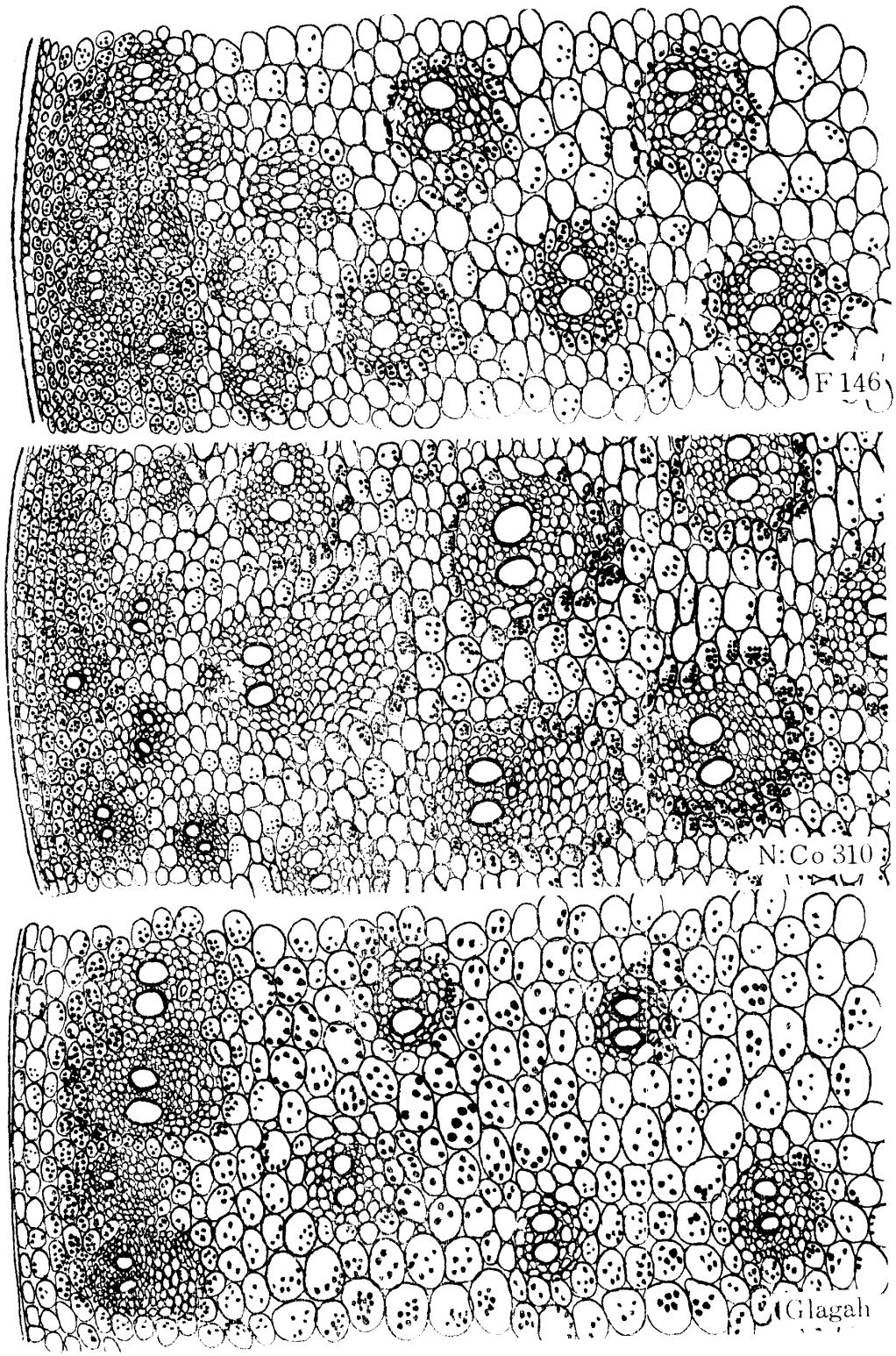

Figure 2.

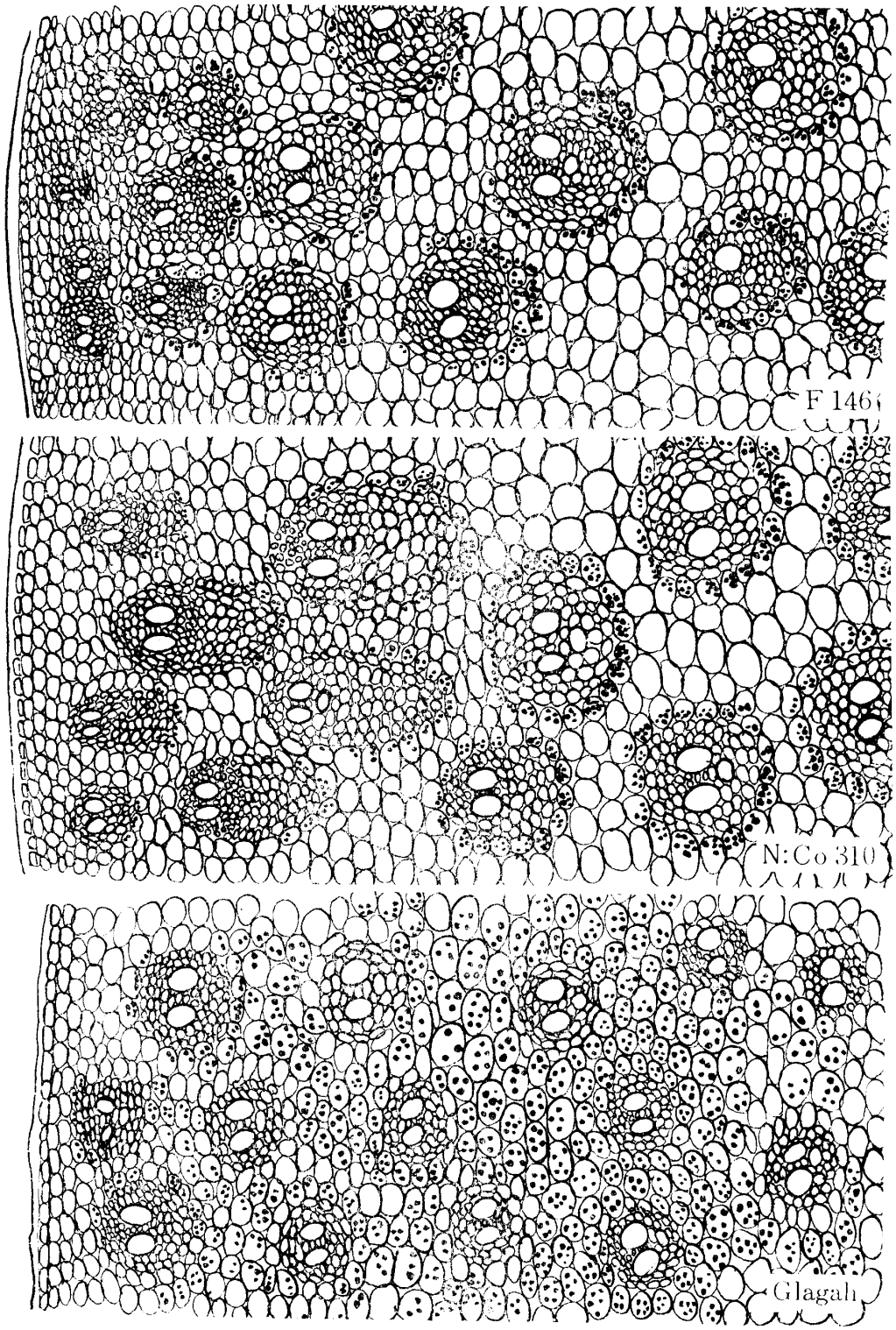

Figure 3.

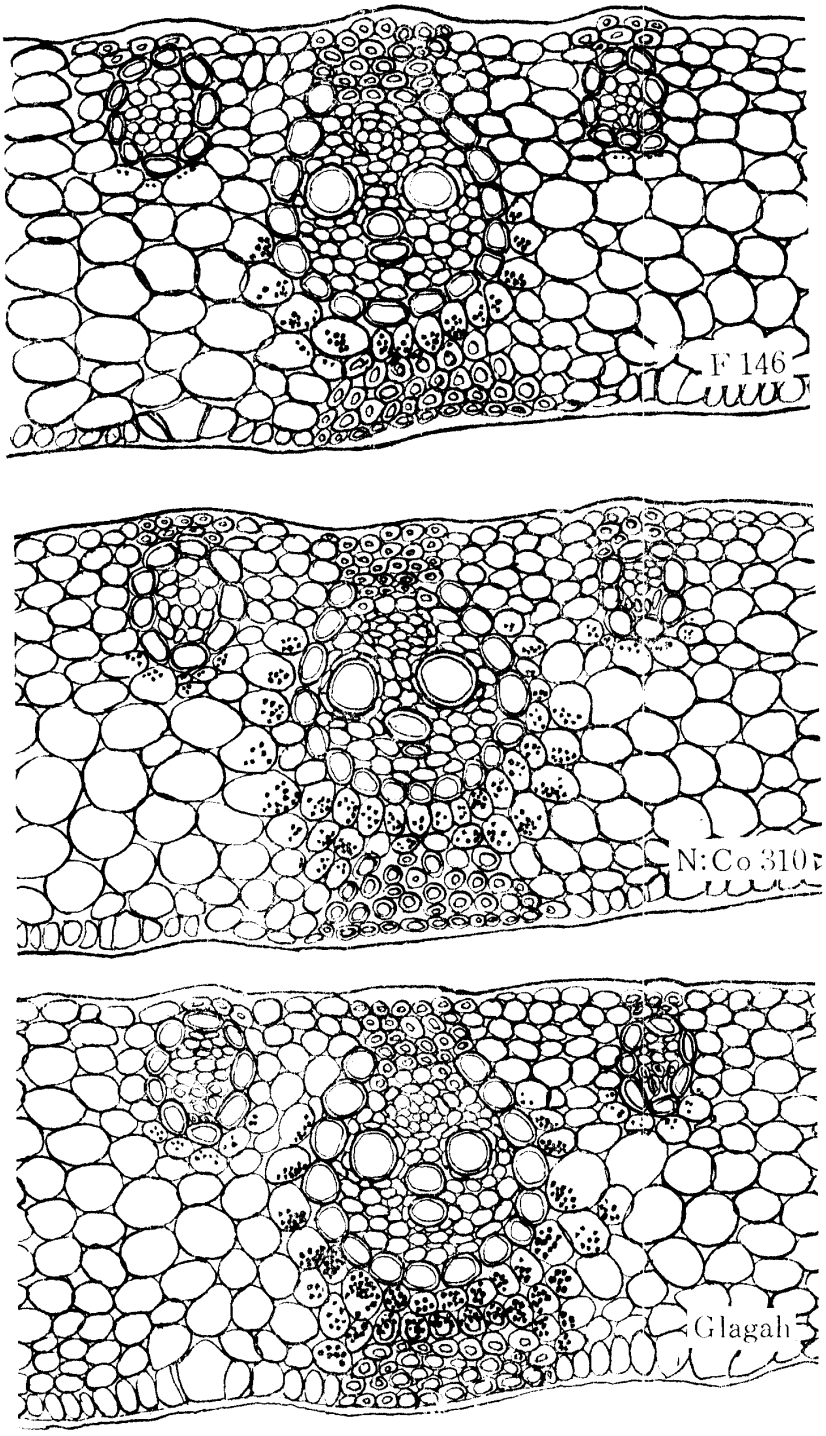

Figure 4.

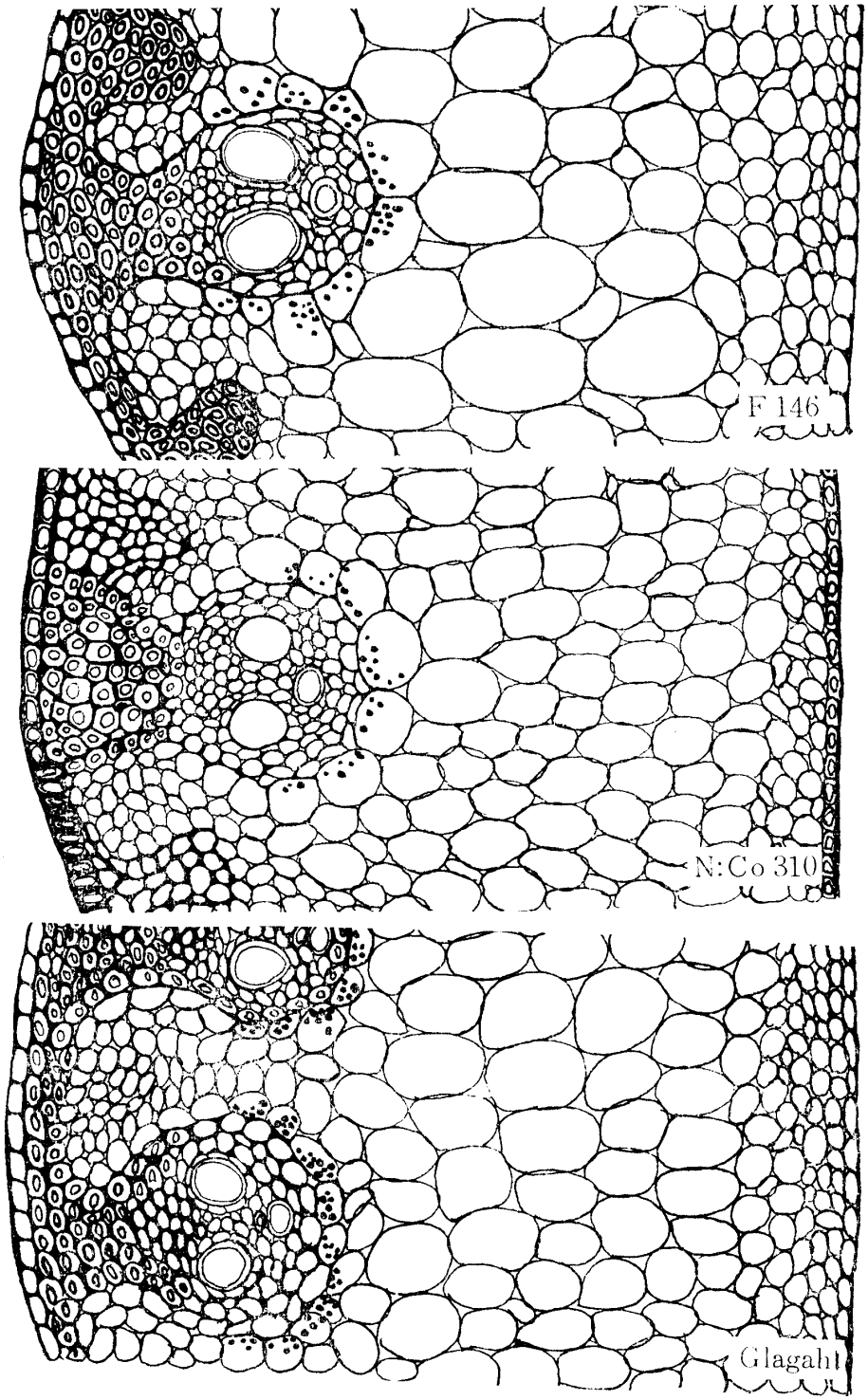

Figure 5.

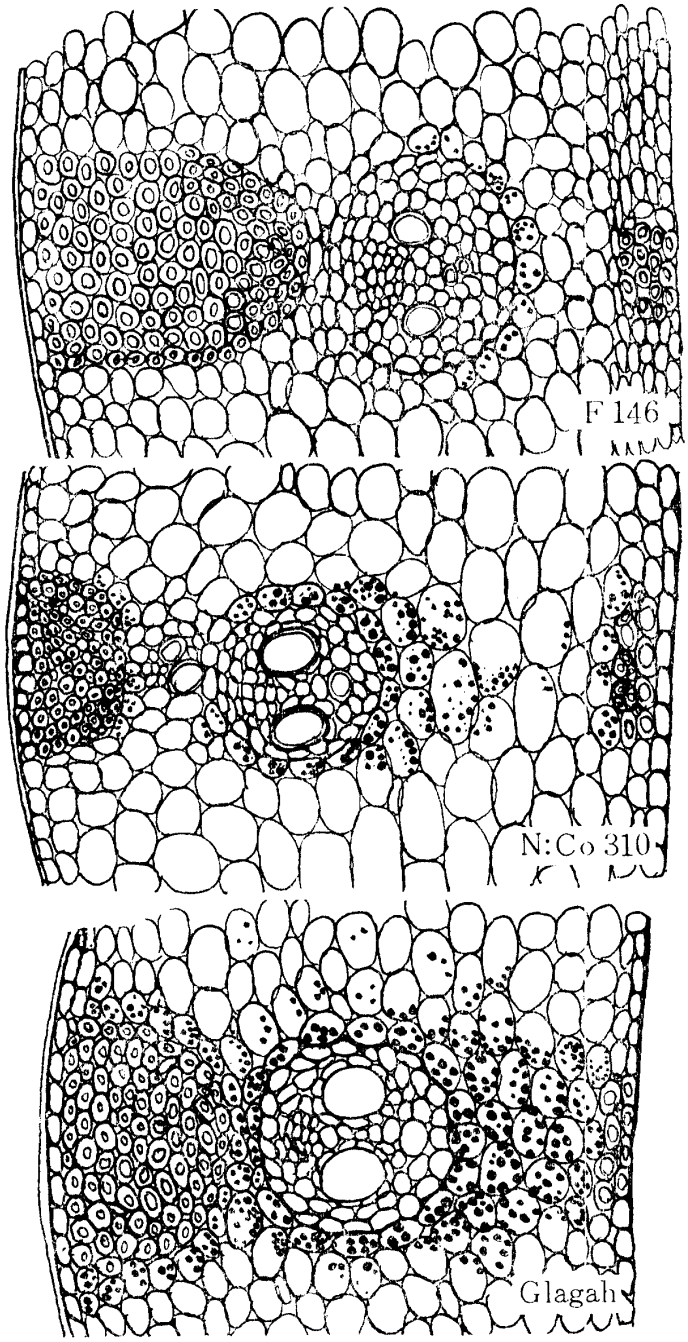

Figure 6.

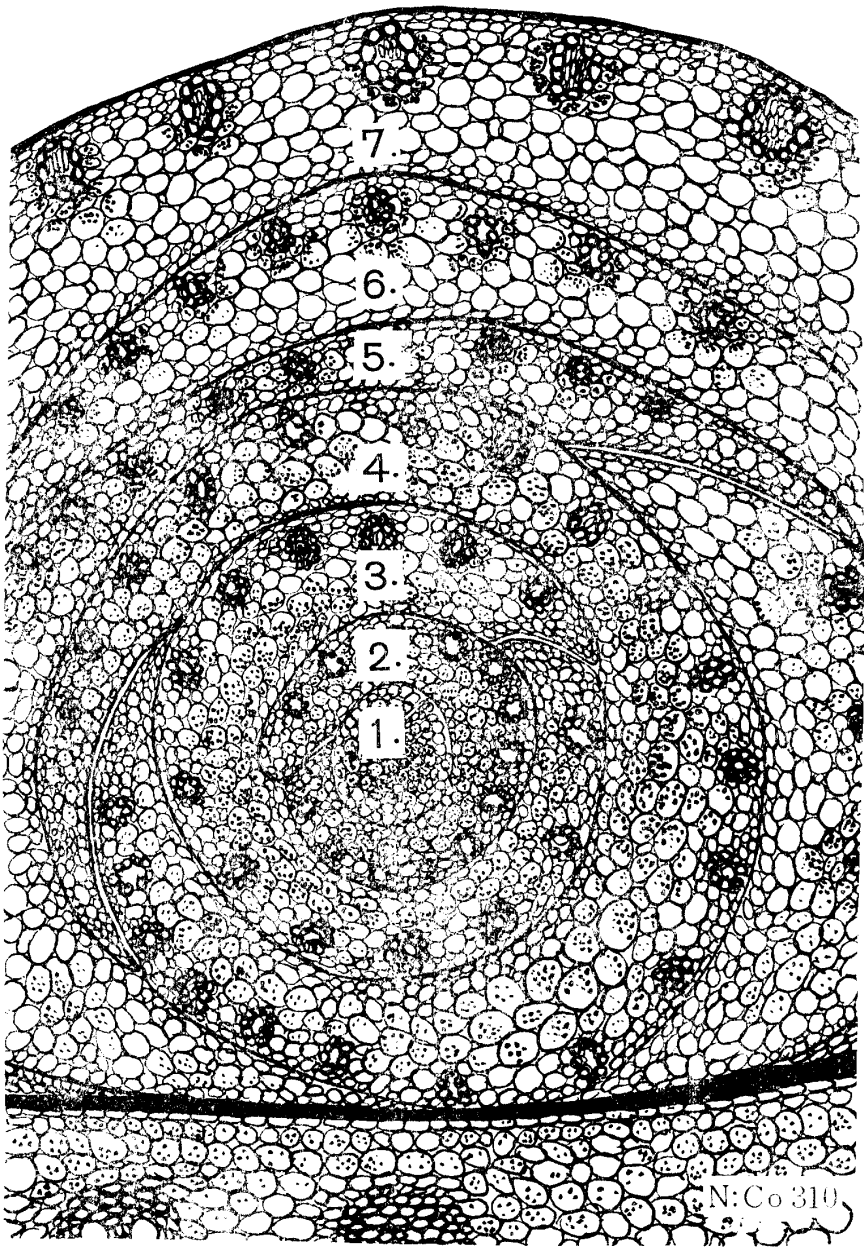

Figure 7.

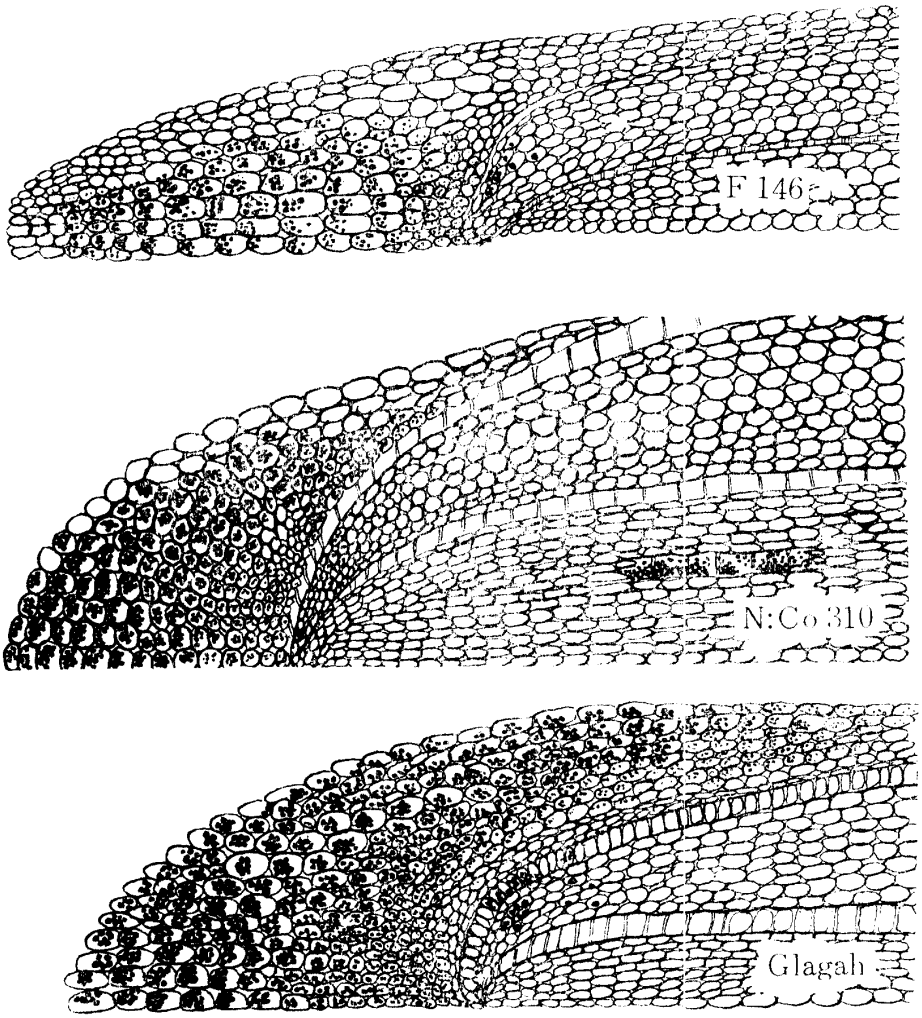

Figure 8.

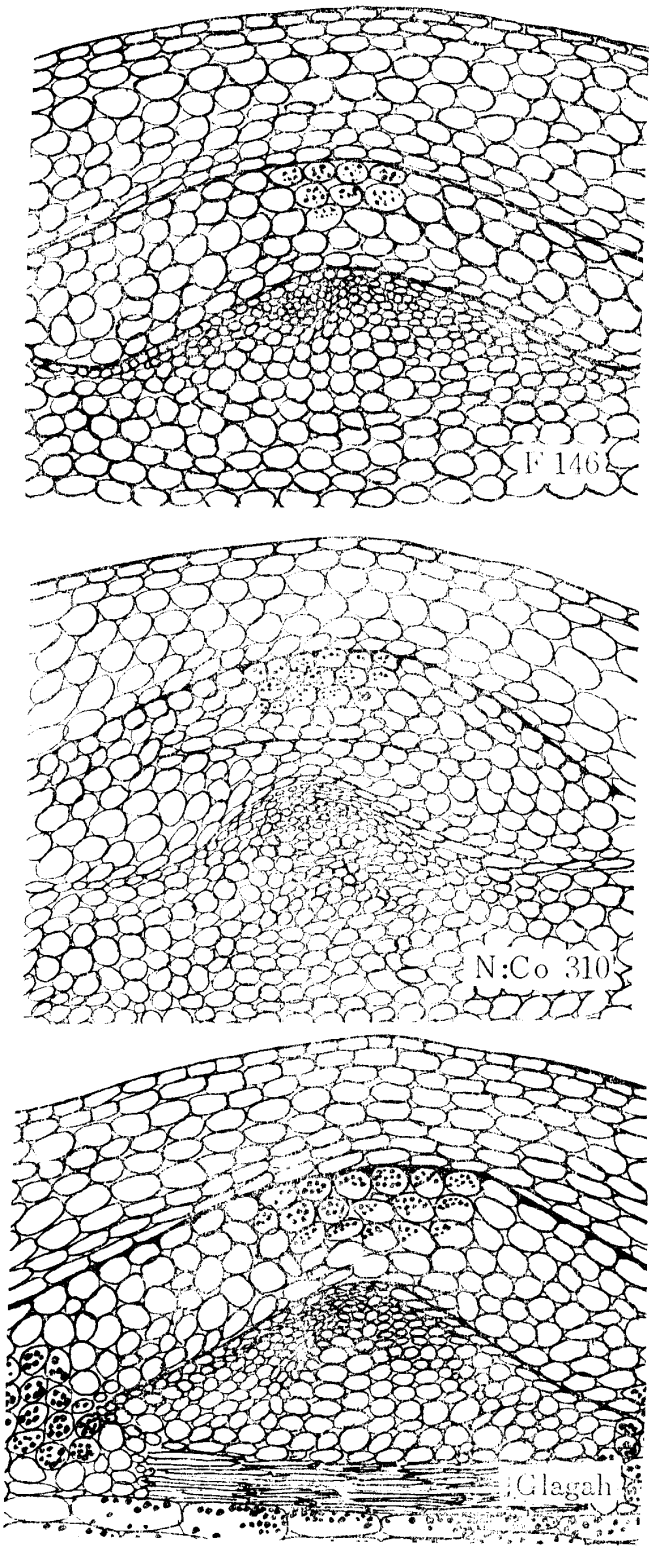

Figure 9.

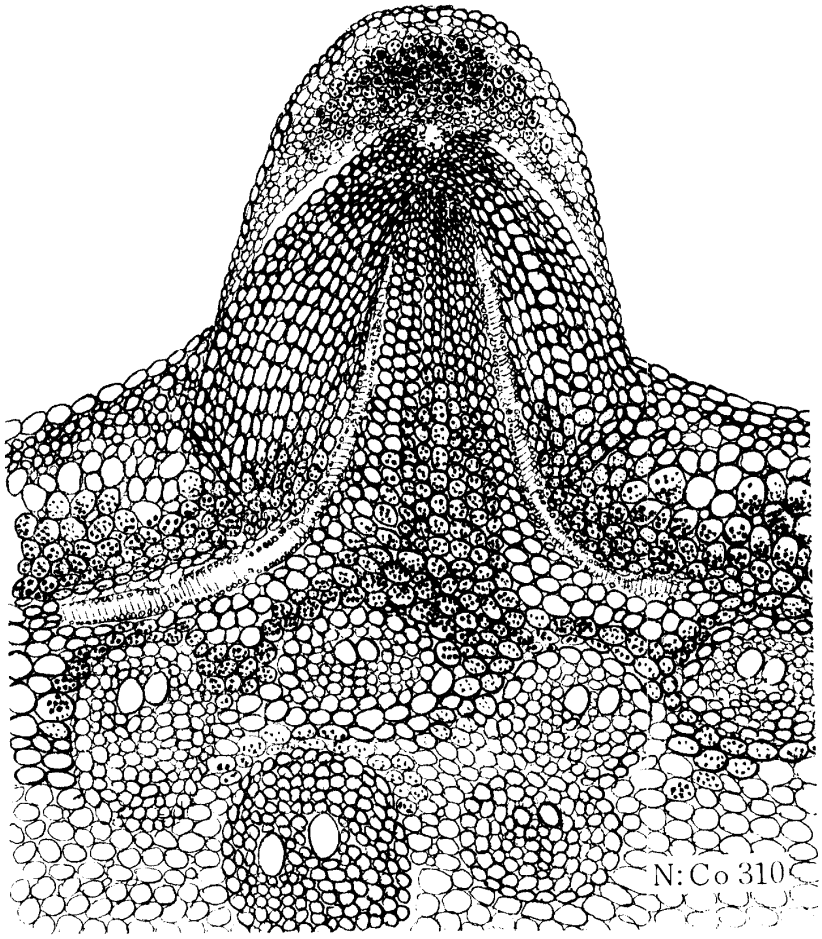

Figure 10.