

Influence of the Interaction of the Mutant In¹ Gene and the Type of Fruiting Branches ss on the Anatomical Features of the Stem in the Indeterminate and Determinant Forms of *G. hirsutum* L.

Akmal A. Yuldashev¹, Guljan M. Duschanova², Miradkham F. Abzalov³, Gayrat N. Jurakulov¹

¹Department of Ecology and Botany of Andijan State University, Andijan, Uzbekistan

²Tashkent Botanical Garden Named after Acad. F.N. Rusanova at the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan

³Institute of Genetics and Experimental Plant Biology, Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan

Email: guljon.duschanova@mail.ru

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Abstract

For the first time, a comparative analysis of the structure of the apical meristem and the node of the main shoot of two forms of the indeterminate kind Namangan-77 and the determinant line of Determinant-2 and Determinant-3 of *G. hirsutum* in the kidney ding phase was carried out. In the apical meristem of the indeterminate form Namangan-77 is characterized by the recessive homozygous state of the mutant gene (in¹in¹) and the dominant homozygous, heterozygous state of the fruiting branch gene S-s: in¹in¹SS, in¹in¹Ss, in¹in¹ss—more pronounced vegetative, vegetative, with this, this form is predominated by the continuation of first-order shoots and the monopodial branching type with unlimited apical growth, accompanied by a uniform elongation of the internodes. In the apical meristem, in the forms of the determinant lines, Determinant-2 and Determinant-3 are characterized by the dominant homozygous state of the mutant gene (In¹In¹) and the recessive homozygous state of the allelic gene (ss)—In¹In¹ss—there is a generative collateral kidney in the axillary leaf axial sinus, which is why these forms of the vegetative apex of the shoot when they transit to the reproductive state turn into a floral apical meristem and a sympodial branching type what happens through the development of inflorescences. Obviously, this is a consequence of a change in the phytohormonal status in the apical part of the stem as a result of the interaction of the mutant gene In¹ and gene S. The node of the main stem in all forms was also studied, and a three-beam-three-lacuna type

of structure was revealed, which is a fairly persistent characterizing feature of large taxa and can be used in their taxonomy.

Keywords

Mutant, Gene, Allele, Anatomy, Stem, Indeterminate, Determinant, Monopodial, Sympodial

1. Introduction

Cotton is a perennial tropical plant that looks like a shrub or small tree, most often used for one season. Favorable conditions provide a very rapid development, and already in the first year of life of the plant go to flowering and fruiting. According to the way of life, the growth and development rates, and the structure of the crown, the various types and forms of cotton are very different. In culture, predominantly early and extremely early forms are used. Such forms of cotton are used as an annual crop.

In the question about the structure of the bush G. S. Zaitsev [1] came to a point of view similar to the views of Lik [2], significantly developed and supplemented the concept. In addition, he developed a coherent theory of the dynamics of the bush morphogenesis [1]. In his works, he adheres to the terminology used by Lik: he calls the kidneys formed in the axils of the leaves, depending on the order of development, the main and adnexal, and the branches—growth, or monopodial, and fruit, or sympodial. The author believes that growth branches arise from the main kidneys in the lower nodes of the main stem, and fruit branches in the upper nodes. Growth branches can also form from the adnexal kidneys in the lower nodes, and fruit branches in the upper ones. Both the main and accessory kidneys in certain places along the stem can remain dormant.

In cotton, the growth of the main stem is, as a rule, indeterminate, and when sufficient conditions are created for the variety of specimens, the height of the plant can reach more than two meters.

Long-term and thorough study of the design and morphogenesis of the cotton bush, various constant forms and hybrids of cotton, belonging to 15 botanical species of the genus *Gossypium* L., is carried out in the work of M. V. Mukhamedzhanova [3]. The study was carried out in various agro-technical and geographical conditions and this allowed us to make a fundamentally important conclusion that any nodal, and probably also the apical kidney of cotton can turn into both a vegetative and generative shoot; that their fate, obviously, depends on the nature of the diet, which in turn is determined by the location of the kidney on the plant, its age, hereditary characteristics and environmental conditions.

Therefore, after reviewing the latest works of V. K. Vasilevskaya [4] and M. V. Mukhamedzhanov *et al.* [3] this issue has acquired special interest for us. The most typical nodes and tops of vegetative and generative branches were investi-

gated. These studies, supplementing the previously available data, led to the creation of a fundamentally new view:

1) Cotton has the ability to produce kidneys of various genesis and biological functions: single, collateral, that is, lateral axillary kidneys, as well as single and serial adventitious, that is, extra-axillary kidneys.

2) Usually in the sinus of the leaf is formed from one to three kidneys, subsequently turning into branches or remaining at rest. Some of them may be embryonic kidneys invisible to the eye.

3) Many of these kidneys and their kidneys do not turn into branches, but remain inhibited, turn into sleeping kidneys or die. They represent a constantly replenished kidney reserve, which serves to enrich and regenerate the crown. The design of nodal renal complexes on different tiers and branches of a plant changes from bottom to top along the main and lateral axes. Single vegetative kidneys usually form in the lower nodes of the main stem and growth branches, vegetative and generative in the middle nodes, and generative collateral kidneys prevail in the upper nodes.

4) The design of nodal renal complexes on different tiers and branches of a plant changes from bottom to top along the main and lateral axes. Single vegetative kidneys usually form in the lower nodes of the main stem and growth branches, vegetative and generative in the middle nodes, and generative collateral kidneys prevail in the upper nodes.

5) The leaf nodes on the fruit branches are characterized by the dominance of the collateral type of generative kidney formation.

Adventive kidneys can form on the hypocotyl, epicotyl, and roots. They are usually vegetative, solitary or serial.

In cotton, as in indeterminate, the height of the plant can be dwarf, short and tall. In zoned varieties, the shape of the leaf blade is generally palmate and palmate, which is controlled, according to Richmond T.R., Harper R. [5] and Stephens S.G. [6] is controlled by the fifth series of one allelic gene. Among the Akstafa-43 varieties, a spontaneous phenotypic mutation has arisen, giving an entire leaf blade at all stages of ontogenesis. In the process of genetic analysis of this mutation, Abzalov M.F., Fathullaeva G.N. [7] [8] experimentally proved that the shape of the leaf blade is controlled by two non-allelic genes O^1-o^1 and In^1-in^1 which, when dominated by homozygosity, blocking O^1 genes forms plants with whole leaf blades. Depending on the combination of the In^1 gene in the dominant homozygous state with the O^1 alleles, the formation of whole-leaf forms is determined—with genotypes ($In^1In^1o^1o^1$ —round-handed, $In^1In^1O^1O^1$ —ovoid-solid, $In^1In^1O^1sO^1s$ —lanceolate whole) with a limiting type of 9 sympodial branches. Moreover, in all these lines, the stem growth is determinant, the stem ends with three or four fruit elements.

2. Materials and Methods

The object of research served indeterminate kind “Namangan-77” with the unsa-

turated type and fruiting branches determinant line determinant-2-determinant of type 3 with the limit fruiting branches (**Figure 1**).

The experiments were carried out in 2018-2019 in the experimental site of the Institute of Genetics and Experimental Plant Biology, Academy of Sciences of the Republic of Uzbekistan, which is located in the Kibray district of Tashkent region. The climate is sharply continental with mild, wet winters and hot, dry summers. The average January temperature is -1°C , July is 36°C . Precipitation—about 300 mm per year.

Simultaneously with the morphological description of the stem, 70% ethanol was recorded for anatomical study. Cross sections of the stem are prepared manually using a safety razor. Cross sections of the stem are made in series. Longitudinal sections are made on the apical part of the stem of the main shoot. Sections were stained with methylene blue and safranin, followed by gluing in glycerol-gelatin [9]. Descriptions of the main tissues and cells are given according to K. Esau [10], N. S. Kiseleva [11]. Microphotographs were taken with a Canon A123 digital camera microphotograph with a Motic B1-220A-3 microscope.

3. Result and Discussion

Based on the genetic analysis [7] [8] [12] of the line of the genetic collection, the leaf blade of the whole leaf mutant L-501, which differs in shape with palmate leaves, palmatisected leaves was proved that the form of the leaf blade is controlled not only by one gene (O_1-o_1), but by the interaction In^1 genes— in^1 .

In the dominant homozygous state, the In^1 gene promotes the formation of whole-leaf lines with altered phenotypically distinct whole leaves, with the $In^1In^1o_1o_1$ genotype round-leaved, $In^1In^1O_1O_1$ round-ovate and with the $In^1In^1O_1^sO_1^s$ gene with a lanceolate leaflet form. The combination of these genotypes with the

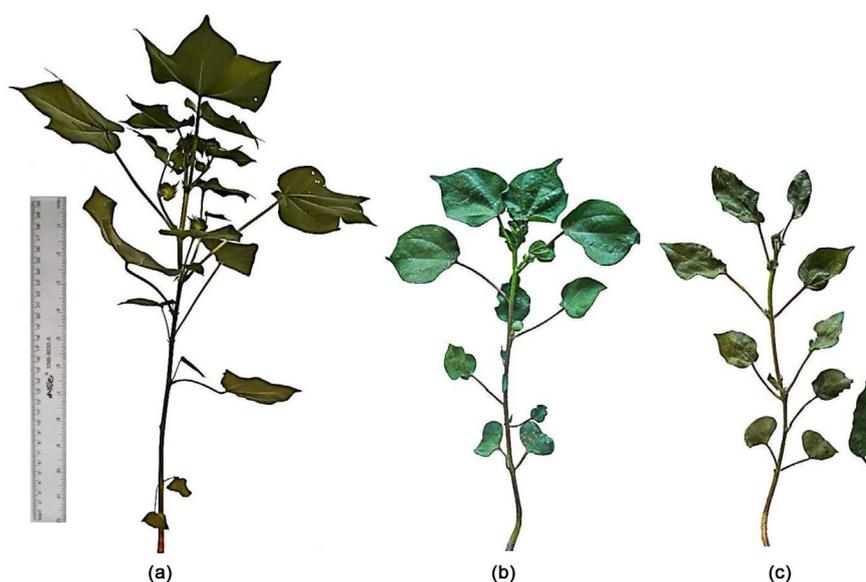


Figure 1. Appearance of the indeterminate and determinant forms of cotton in the phases of budding: (a) Namangan-77, (b) Determinant-2, (c) Determinant-3.

recessive homozygous state of the fruit branch gene ($ss—In^1In^1o_1o_1ss, In^1In^1O_1O_1ss, In^1In^1O_1^sO_1^ss$) first forms the kidney ding phase of the determinant growth type of the main stem. In case of recessive homozygous (in^1in^1), a palmate leaf, $in^1in^1o_1o_1$ palmate leaf, and $in^1in^1O_1O_1$ super palmate leaf are formed with the $in^1in^1O_1^sO_1^s$ genotype. The combination of these genotypes in the form of a leaf blade, regardless of the allelic state of the S-s gene (SS, Ss, ss), the type of growth of fruit branches of the main stem becomes indeterminate.

To clarify the anatomical changes in the indeterminate and determinant forms we studied the typical nodes and tops of vegetative and generative shoots in two forms of the indeterminate kind Namangan-77 and the determinant line Determinant-2, Determinant-3.

Cotton has three main types of kidneys: the apical kidney of the main stem arising from the germinal kidney—the plume sitting between the cotyledons at the upper end of the mesocotyl, axillary (sinus), or nodular kidneys that occur in the axils of the leaves, and extra-axial adventitious (accessory) kidneys sometimes occurring on the hypocotyl, epicotyl and other organs of the aerial part of the plant, on the root neck and roots.

On the paradermal section, the apical part of the meristem of the apical autonomic and generative shoots of the indeterminate kind Namangan-77 and the determinant lines of the Determinant-2 and Determinant-3 of cotton in the kidney ding phase were studied.

1) The indeterminate variety Namangan-77 is most pronounced in the apical meristems at the apex of the vegetative and generative kidneys of the 1st node of the monopodial branch of the main stem, consisting of kidneys of leaves, apical kidneys, second-order kidneys, two kidney kidneys and conductive leaf bundles. According to the function performed, two main types of kidneys are distinguished—vegetative and generative (flower). Vegetative and generative kidneys are very dramatically different in their structure, development and biological functions. Vegetative kidneys, including the apical kidney of the main stem, when developing, turn into growth shoots of a monopodial structure with unlimited apical growth, accompanied by a uniform elongation of the internodes (**Figure 2**).

2) The determinant lines Determinant-2, Determinant-3—in the apical meristems of the apex there is a generative kidney in the leaf sinus on the sympodial branch of the main stem, consisting of leaf primordial, two primordium buds, terminal kidney, main axillary kidney, primordium of the second terminal bud and conductive leaf bundles. A fruiting kidney, developing, turns into a short fruit twig with one internode—a peduncle, one bract of leaf and an apical flower sitting on a peduncle articulated with a peduncle. Sometimes the bracts, as well as the fruit branch, are partially or completely reduced, and then the generative kidney gives an axillary flower. This is as follows: the growth cone in the vegetative kidneys is more convex, it is surrounded by several asymmetric primordiums of leaf organs—leaves and stipules. The cone of growth at the anlage

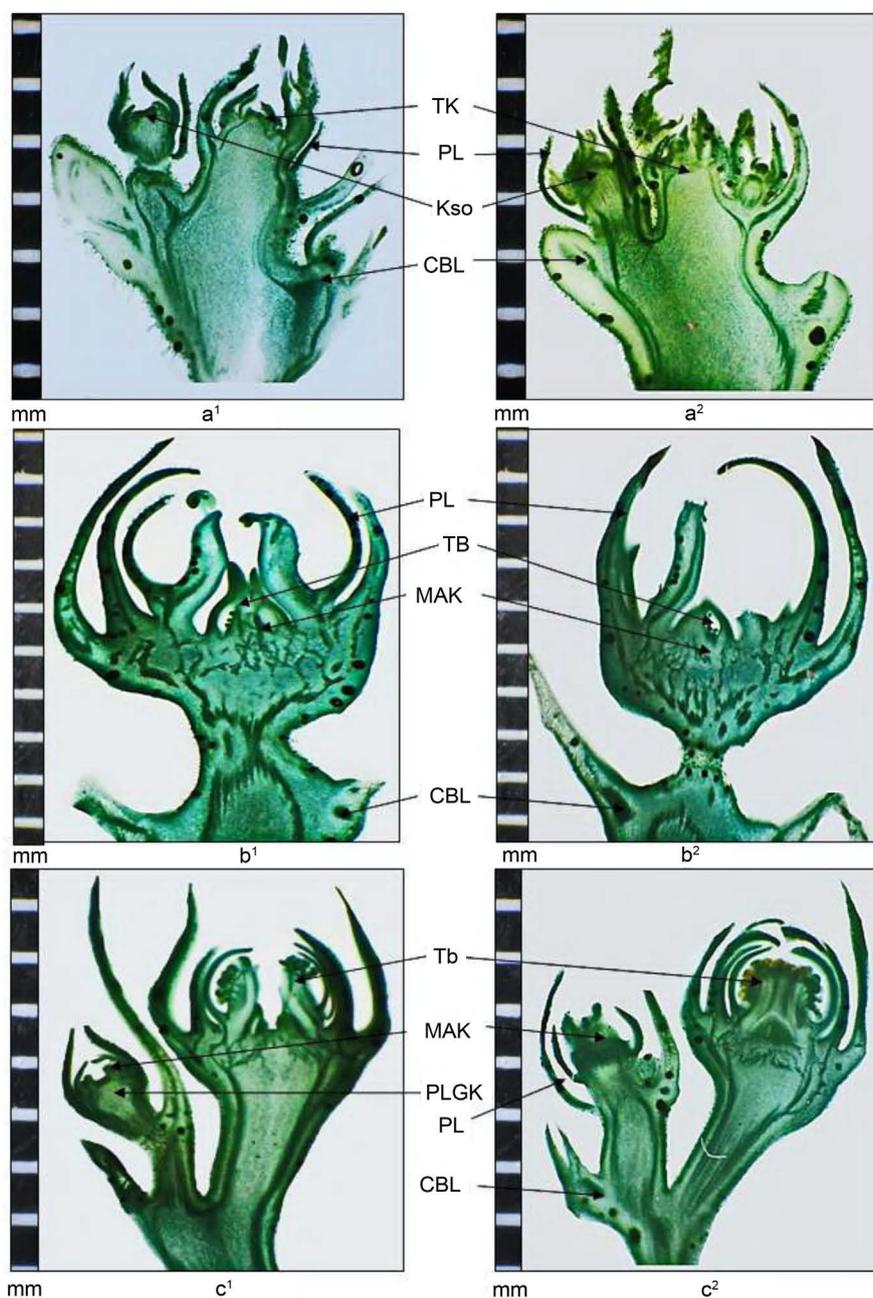


Figure 2. Anatomical structure of the top of the main shoot in a longitudinal section of the shape of cotton: a¹-a²—indeterminate kind Namangan-77; b¹-b²—Determinant-2; c¹-c²—Determinant-3. Legend: PLGK—the primordium of the lateral generative kidney, TK—the top of the kidney, MAK—the main axillary kidney, PL—the primordium of leaves, Kso—the kidney of the second order, CBL—conducting bundles of the leaf, TB—terminal bud.

of the generative kidney, flattened and somewhat widened, is surrounded by symmetrical primordium of the flower parts: bracts, calyx, and others. There are two rudiments of leaves on the fruit kidney. Usually there is an embryo of only one bract leaf and two stipules. The generative kidney at this stage turns into a rudimentary kidney with clearly distinguishable symmetrical kidneys of all parts

of the flower, bracts, calyx, corolla, stamen column and pistil.

The pedicel at this stage begins to lengthen and becomes thin, and the head of the kidney expands greatly. At the same time, the rudiments of a single internode are differentiated—a peduncle and a bract with a pair of stipules. In the bosom of the leaf, between it and the leg of the first kidney, one or two rudimentary generative kidneys appear. Generative collateral kidneys prevail in the upper nodes of the main stem. Vegetative shoot apex when they transition to a reproductive state turns into a floral apex, which occurs through the development of inflorescences. Therefore, the reproductive apex form of the determinant is considered as a floral apical meristem (**Figure 2**).

A comparative analysis of the structure of the apical meristem of the main shoot of two forms of the indeterminate variety Namangan-77 and the determinant line of Determinant-2 and Determinant-3 of cotton in the kidney phase was carried out. It was revealed that the vegetative and generative kidneys of the main stem, consisting of the top of the kidneys, second-order kidneys, are more pronounced in the form of the indeterminate variety “Namangan-77” in the apical meristem, and in this connection, this form is dominated by the continuation of first-order shoots and the monopodial branching type with unlimited apical growth, accompanied by a uniform elongation of the internodes. The determinant-2 and determinant-3 determinant lines have a generative kidney in the axillary leaf axial sinus in the apical meristem, and generative collateral kidneys consisting of leaf primordium, two primordium buds, a terminal bud, the main axillary kidney and the rudiment of the second terminal bud, in connection with which, these forms of the vegetative shoot apex upon their transition to the reproductive state turn into a floral apical meristem and a sympodial branching type, what happens through the development of inflorescences. In the form of the determinant lines of determinant-2 and determinant-3 of cotton with the limiting type of generative branches in the sinus of the first leaf of the fruit branch, all kidneys give axial flowers and bolls. In such cases, one terminal and one, two or three axillary flowers are formed at the end of the branch.

3) The anatomical structure of the nodes of the main stem

The dependence of the development of the conductive apparatus of the stem on the lateral organs and in the further study of the conductive system of higher plants based on the theory of leaf and branch traces was dealt with by V. K. Vasilevskaya [4], S. F. Zavalishina [13], E. A. Mokeeva [14], E. A. Kondratiev-Melville [15], F. G. Kamilova [16], Garaeva F. Z. [17].

The node type is a fairly persistent trait characterizing large taxa and is widely used by taxonomists. The most characteristic for most of the dicotyledons, especially for more primitive groups, is the three-lacunar knot, from which single-lacuna and multi-lacunae originated [13] [18] [19].

At the nodes, the structure of the conducting system is more complicated than at internodes, since here there is a connection of leaf and branch traces with the conducting system of the main stem. A branch track is a conductive lateral shoot

system or an axillary kidney that has not yet developed into a shoot. Procambial cords, from which bundles of leaf and branch traces subsequently differentiate, as they approach the educational ring, they block the development of procambium in it, and for some extent the cells of the educational ring differentiate into parenchymal cells.

In the stems in which the differentiation of the primary conductive tissues has ended, these parenchymal cells make up the so-called leaf breaks (gaps) and branch breaks. They represent zones along which bundles of leaf and branch traces gradually connect with the conducting system of the main stem, and its internodes restore the structure characteristic of this plant.

In the compared forms of the indeterminate variety “Namangan-77” and determinant lines of the Determinant-2 and Determinant-3 cotton in the kidney ding phase, the nodes of the three-beam three-hole type. The complete merging of bundles of leaf traces with a conductive system, axis occurs very, quickly—in the upper third of the corresponding internode. In the middle of the internodes, a continuous ring of the conductive shoot system is already observed in only the perimedular zone of the core, the contours of leaf traces are visible (**Figure 3**).

Leaf traces form in the area of the node as a result of the merger and rearrangement of petiole bundles. Additional bundles usually appear as a result of the incomplete influence of the bundles, which, when approaching the stalk of the stem, are again split off (most often from the median, less often from the lateral) each independently enter through the corresponding gap. Additional bundles, as a rule, are smaller than the main ones. The nodes of the generative shoots are three-beam three-hole and differ from the vegetative ones according to their morphological structure. The main and axillary shoots are equivalent internodes that make up the generative branch, and in the node the conducting system forms two equivalent rings, one of them is the follow of the axillary shoot, from which the next internodes of the generative branch are formed, and the other ring is the trace of the lower internode of the shoot ending in a flower. The leaf cushion and the conductive bundles of the main and axillary shoot on the cross section of the node are not located in one line, but are displaced at an angle so that the conductive ring of the axillary shoot protrudes at the top. The branch traces, compared by the shape of cotton, are represented by a single arched conductive bundle in which a gap is formed for the median bundle of the leaf trail. A comparative analysis of the main shoot node in the indeterminate and determinant forms of cotton *G. hirsutum* L., which differ from each other in the formation of renal traces: in the indeterminate kind “Namangan-77”, one renal trail was noted, in the determinant line—2-4 renal traces. The node of the main stem in all forms was studied and the three-beam three-lacuna type of structure was revealed.

4. Conclusion

A comparative analysis of the structure of the apical meristem and the node of

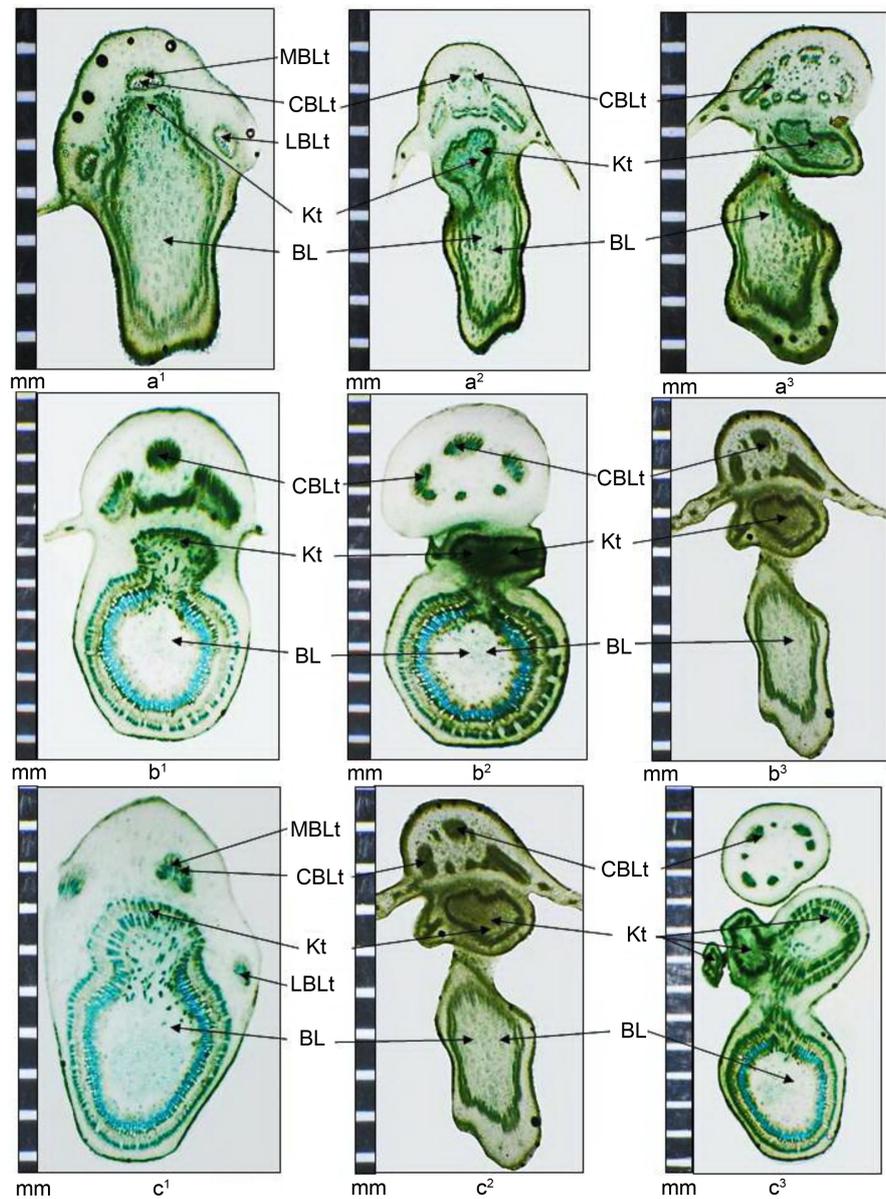


Figure 3. The anatomical structure of the three-beam three-hole type of the first node of the main stem in a longitudinal section of the shape of cotton: a¹-a³—indeterminate kind Namangan-77; b¹-b³—Determinant-2; c¹-c³—Determinant-3. Legend: BL—branch lacuna in the main stem, LBLt—lateral bundles of the leaf track, MBLt—the median bundle of the leaf tracks, CBLt—the conducting bundles of the leaf tracks, Kt—the kidney track.

the main shoot of two forms of the indeterminate kind Namangan-77 and the determinant line of Determinant-2 and Determinant-3 of cotton in the kidney ding phase was carried out. In the apical meristem of the indeterminate form Namangan-77 is characterized by the recessive homozygous state of the mutant gene (in^1in^1) and the dominant homozygous, heterozygous state of the fruiting branch gene S-s: in^1in^1SS , in^1in^1Ss , in^1in^1ss —more pronounced vegetative, vegetative, with this, this form is predominated by the continuation of first-order shoots and the monopodial branching type with unlimited apical growth, ac-

accompanied by a uniform elongation of the internodes. In the apical meristem, in the forms of the determinant lines, Determinant-2 and Determinant-3 are characterized by the dominant homozygous state of the mutant gene (In^1In^1) and the recessive homozygous state of the allelic gene (ss)— In^1In^1ss —there is a generative collateral kidney in the axillary leaf axial sinus, which is why these forms of the vegetative apex of the shoot when they transit to the reproductive state turn into a floral apical meristem and a sympodial branching type what happens through the development of inflorescences. Obviously, this is a consequence of a change in the phytohormonal status in the apical part of the stem as a result of the interaction of the mutant gene In^1 and gene S . The node of the main stem in all forms and the revealed three-beam three-lacuna type of structure is a fairly persistent characterizing feature of large taxa and can be used in taxonomy.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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