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EAR AND TASSEL DEVELOPMENT IN MAIZE

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A study of the changes that take place in the growing points which form the ear and tassel of maize, or Indian corn, reveals a number of relationships that cannot be seen in the mature plant. It shows how the parts of the ear and tassel are formed from the growing point; where the parts are placed in relation to each other; and the sequence of the differentiation of the parts. Such a study is focused on the beginning rather than on the end of the developmental cycle and as a consequence a better understanding can be attained of variations in certain characteristics such as ear row number, ear height, time of sexual maturity, and of certain correlations in the development of the tassel and ear.

This paper will be limited to a description of the differentiation and development of the ear and tassel of the corn plant. Normal development will be emphasized; however, a description of certain abnormal ear types will be included. Part of the photomicrographs were published earlier (Bonnett, 1940) and are used again in this paper because they show clearly the various developmental stages of the ear and tassel and their parts. The descriptions of these illustrations have been revised.

LITERATURE REVIEW

Certain authors have made extensive reviews of the literature on the morphology of corn and other grasses. Literature on the general morphology of the corn plant has been reviewed by Weatherwax (1916, 1917, 1925), Miller (1919), Arber (1934), and Randolph (1936). Evans and Grover (1940) have a good literature review on the morphology of grasses.

The general morphology of the tassel and ear of the corn plant has been described by Collins (1919), Weatherwax (1916, 1917, 1925), and Arber (1934). Pistillate spikelet development was clearly described by Miller (1919). Randolph (1936) described the development of the caryopsis as well as the pistillate spikelet.

Few studies of the early stages in the development of the ear and tassel of corn have been published. Noguchi (1929) described some of the beginning stages in the development of the ear and tassel. Development of the ear and certain of its characteristics were described by Fujita (1939). A detailed description of the development of the ear and tassel, illustrated by photomicrographs, was published by Bonnett (1940).

Publications dealing with corn morphology from certain specific viewpoints should also be mentioned. A paper by Anderson (1944) on the homologies of the ear and tassel is of value to both the corn breeder and the student of corn morphology. Mangelsdorf has brought together the pertinent information on the morphology of the ear as it is related to the question of the origin and nature of the corn ear. A paper by Cutler (1946) and one by Brown and Anderson (1947) describe morphological details of the ear and tassel of special types of corn.

MATERIALS AND METHODS

First-generation hybrid plants, Golden Cross Bantam (Purdue Bantam 39 × Purdue 51) and a Country Gentleman hybrid (Illinois 8 × Illinois 6) sweet corn, were used in working out the details of tassel and ear development. Plants of first-generation hybrids are genetically alike and variation among individual plants is slight, which makes it easier to follow the developmental sequences. The sweet corn plants were grown in the greenhouse in two-gallon jars. Plants of the other ear types were grown in the field.

Seed of the various ear types was obtained from different sources. The Maize Genetics Cooperation, Cornell University, Ithaca, N. Y., furnished seed of 4-row and ramosa. Seed of Longfellow flint and Japanese Hull-less came from William L. Brown, Pioneer Hi-Bred Corn Company, Johnston, Ia. R. R. St. John, DeKalb Hybrid Seed Company, Champaign, Ill., supplied seed of Mexican Long Kernel.

Most of the photomicrographs were taken of living material which was handled as was described by Bonnett (1940). However, tassels and ears of the different ear types were killed and fixed in a formalin—acetic acid—alcohol solution and later dissected and photographed.

PLANT DEVELOPMENT

The beginning of the differentiation of the tassel can be approximately determined by counting the number of leaves or by examining the base of the plant to see if internode elongation has begun (pl. 31). Leaf number is less reliable owing to the fact that early types have fewer leaves than late ones at the time tassel differentiation begins and to the effect of the environment upon the relation between leaf number and tassel differentiation. Beginning of internode elongation has been found to be associated with the beginning of tassel differentiation (pl. 31). However, when it can be determined from an external examination of the plant that the basal internodes are elongating, the earliest stages of tassel development have usually been completed. The only reliable method of determining when tassel development begins is to dissect the growing point of the main shoot and look at it with a dissecting microscope. If sampling begins early enough and is done at frequent intervals the beginning of tassel development can be accurately determined.

Initiation of ear development is behind the initiation of tassel differentiation. Silking may be synchronized with shedding or it may be ahead of or after pollen shedding on the same plant. Silking date and its synchronization with pollen shedding varies with the variety and with growing conditions.

TASSEL AND STAMINATE SPIKELET DEVELOPMENT

The shoot of the corn plant, like that of other cereals (Bonnett, 1935, 1936, 1937, 1940) and grasses (Evans and Grover, 1940; and Weber, 1938, 1939), passes through two stages in its development from germination to the dehiscence of the anthers. During the first stage, leaf fundaments, leaves, and axillary shoots are produced and the internodes of the stem remain short. During the second stage the internodes of the stem elongate, the tassel and its parts differentiate and develop, and the axillary shoot or shoots (ear or sucker) pass through their various stages of development.

Two growing points (pl. 24, A and B) represent the appearance of the shoot in the first stage of development. The growing point (pl. 24, A, *gp*) is partly enclosed by two leaf initials. At this stage of development the growing point is much smaller in relation to the diameter of the stem than the growing point of either wheat, oats, or barley at a similar stage of development.

Two processes, which occur simultaneously, indicate the beginning of the second stage of development: (1) The internodes of the stem begin to elongate, and (2) the growing point elongates in preparation for the differentiation of the tassel and its parts. Tassel development is completed when the anthers dehisce.

Branch primordia are the first of the tassel parts to differentiate (pl. 24, C, *b*, and D, *b*). They arise in acropetal succession as lateral projections from all sides of the elongated central axis. Some of the branch initials at the base of the central axis elongate and become the lateral axes of the tassel (pl. 24, E, b_1). The other initials arising from a point higher on the central axis are the ones from which the spikelet initials originate (pl. 24, C, *b;* D, *b;* E, *b;* F, *si;* and G, *si*). It should be noted that, in the early stages of tassel development, so far as external appearances indicate, there are no differences between those initials that become the lateral branches of the first order and those from which the spikelet initials differentiate. Therefore, all of the first initials to appear are branch initials.

As has been described for oats (Bonnett, 1937) and grasses (Evans and Grover, 1940), branches of the second order may rise by budding from the base, and at the lateral margins, of the branches of the first order (pl. 24, E, b_2, and K, b_2). It has already been stated for the central axis that those initials of the lateral axes above the most basal ones are the primordia from which the spikelet initials differentiate.

In studies made on barley, wheat, and oats (Bonnett, 1935, 1936, 1937) and grasses (Evans and Grover, 1940), there was always an indication of leaf fundaments on the central axis in the axils of which the lateral shoots of the inflorescence were formed. Although there is no indication of leaf fundaments subtending the initials of the lateral shoots of the tassel of the sweet corn studied, in certain other types of corn they have been found. There are structures apparently homologous with leaf initials, subtending the lateral shoots of the ear (pl. 26, C, *l*).

All the branches of the tassel are indeterminate. Neither the central axis (pl. 24, I, *t*) nor the lateral axes (pl. 24, J, *t*, and K, *t*) of the tassel terminate in apical spikelets. Primordia from which the spikelet initials differentiate are produced acropetally as long as the axes increase in length.

In the beginning of spikelet development the branch initial divides into two unequal parts, the spikelet initials (pl. 24, F, *si;* G, *si;* and H, *si*). The spikelet that develops from the larger spikelet initial is pediceled (pl. 25, E, *s'*) and the one from the smaller initial is sessile (pl. 25, E, *s*). The larger initial is always in advance of the smaller in its development. This is shown by the beginning of development of the empty glume on the larger initial in plate 24, H, *e*, and the lack of such development in the smaller initial, and by the beginning of anther differentiation in the larger spikelet in plate 25, C, *s'*, and the lack of anthers in the smaller spikelet (pl. 25, C, *s*).

Several of the early stages of spikelet development can be seen in plate 24, H, which shows a group of spikelets from the central axis of the tassel. Beginning at the top of the photograph, the developmental stages range from an undifferentiated lateral shoot initial, through the various stages of division into spikelet initials, to the beginning of development of the empty glumes. The empty glumes are the first of the spikelet parts to form and are first seen as transverse ridges across the spikelet initial (pl. 24, H, *e*). They grow in length and finally enclose the flowers (pl. 25, I). Spikelet initials develop from all sides of the central axis of the tassel (pl. 24, G) but only on the abaxial side of the lateral branches. The abaxial side of branches of the first and second order are shown in plate 24, K, b_1, b_2, and the adaxial side of a branch is shown in plate 24, J. Two rows of lateral shoot primordia develop, and they divide into two pairs of spikelet initials.

At any stage of development the central axis of the tassel is in advance of the branches (pl. 24, F, L, and M). This is what should be expected since the central axis is formed first and the branches differentiate from it. The branches increase considerably in size before the initials from which the spikelets differentiate are produced.

In each staminate spikelet two flowers develop from the meristem located above the empty glume initials (pl. 24, H, *gp'*). The meristem divides into two unequal parts. The larger part gives rise to the upper flower (pl. 25, A, fl_1, and B, fl_1) and the smaller part develops into the lower flower (pl. 25, A, fl_2, and B, fl_2). These flowers differ in their rates of development. The anthers of the upper flower (pl. 25, A, fl_1; B, fl_1; D, fl_1; and G, fl_1) differentiate first, and their development is always ahead of the corresponding parts of the lower flower (pl. 25, A, fl_2; B, fl_2; D, fl_2; and G, fl_2). As the flowers approach maturity the anthers of the lower flower attain nearly the same size as those of the upper flower (pl. 25, G, fl_1, and fl_2).

Anther initials are the first of the flower parts to differentiate (pl. 25, A, *an,* and B, *an*). Since the tassel flowers are staminate, anther differentiation and development are the principal growth activities within the flower. Pistils may develop from the meristem located above the anther initials (pl. 25, A, *p*) but they usually remain rudimentary (pl. 25, B, *p*). Under certain conditions of growth the pistil may show considerable development (pl. 25, F, *p*) and may become fully developed and functional. Flowering glumes develop for each flower, but they are so thin (pl. 25, G, *g*) that they are difficult to distinguish at the beginning of their development. The lemma and palea begin their development as thin ridges at a point on the meristem just below the anther initials (pl. 25, B, *g*) at about the same time that the anther initials begin to differentiate.

Deviations from the normal development under field conditions are often seen in plants grown in the greenhouse. Normally one spikelet is sessile and the other pediceled (pl. 25, E), but both spikelets may be sessile (pl. 25, H). Another type of deviation which will be described later is the development of functional pistils in the tassel.

EAR AND PISTILLATE SPIKELET DEVELOPMENT

In the early stages of stem development a shoot is produced in the axil of each leaf, but at a later stage axillary shoots are no longer produced. The cessation of axillary shoot development seems to be associated with the elongation of the internodes of the stem and the development of the tassel.

Ears develop from the upper one or more axillary shoots of the stem. Those shoots, formed at the base of the stem, may remain non-functional or develop into suckers. If an examination is made at the time the topmost shoots are producing ear initials, it will be found that the growing points of the basal shoots are producing only leaf fundaments; but they are more and more advanced in development from the base to the top of the stem. Axillary shoots develop in acropetal succession and during the early stage of stem development they become larger in succession from the apex to the base of the stem. Later, when the ears begin to develop, the size sequence changes, so that the topmost shoot is the largest and the shoots become smaller from the top to the base of the plant. The topmost shoot or the topmost two or three shoots, depending upon whether they are single- or multiple-eared types, in turn take precedence in their development or they may inhibit the development of the shoot immediately below. This difference in development is shown by the size of the ear initials in plate 26, I, J, and K, which are the ear initials from the topmost, second, and third shoots, respectively. The axillary shoot is enclosed in a strongly keeled prophyllum (pl. 26, A, *pr,* and B, *pr*) which may be entire or divided. Leaf initials that develop into husks are covered by the prophyllum.

Ear differentiation is indicated by an elongation of the growing point of the axillary shoot and the differentiation of lateral projections from the central axis of the ear initial (pl. 26, C, and D). The lateral projections are the branch initials from which the spikelet initials differentiate, and correspond to the branch initials that first appear on the central axis and branches of the tassel. Subtending each initial, as has already been mentioned, are ridges (pl. 26, C, *l*) which are similar to the subtending leaf initials that appear in the differentiation of the inflorescences of barley, oats, and wheat. These ridges increase in size and form the cup-like depressions (alveoli) in which the spikelets occur (pl. 28, B, *x*).

Spikelet initials are produced in pairs by the division of the preceding initial into two unequal parts (pl. 26, E, *si*). Thus in the ear there is potentially a pediceled and a sessile spikelet from each branch initial, as in the tassel, although the subsequent development of the spikelets do not seem to bear this out. While the parts of the larger of the pair of spikelet initials begin to differentiate before those of the smaller spikelet initial, the difference in their development is not so great as was pointed out for the spikelet initials of the tassel. The empty glumes are the first of the spikelet parts to form and can be seen as transverse ridges across the spikelet initial (pl. 26, F, *e*, and pl. 27, A, *e*). More advanced stages of development of the glumes are shown in plate 26, G, *e*. As the empty glumes increase in length, they enclose the ovary, but the silk extends beyond them (pl. 27, K, *e*).

The number of rows of kernels per ear is determined by the number of rows of branch initials that differentiate. Each branch initial divides into two spikelet initials and each spikelet initial has one fertile flower in which a kernel is produced. This pattern of development results in an even number of rows of kernels. However, row number is actually determined by the number of rows of branch initials (pl. 26, E) that are produced on the ear initial.

Straightness of the rows of kernels has been shown to be related to the number of rows of branch initials on the ear (Fujita, 1939). If the number of rows of branch initials is even, 4, 6, 8, etc., resulting in 8, 12, 16, etc. rows of kernels, the rows will be straight, making a balanced, symmetrical ear (Mangelsdorf, 1945). If the number of branch initials is odd, 3, 5, 7, etc., resulting in 6, 10, 14, etc. rows of kernels, the rows will be twisted, making an unbalanced, asymmetrical ear. Mangelsdorf (1945) has pointed out that this relationship applies to North American and other varieties of corn which have *Tripsacum* contamination but in Bolivian and Peruvian corn, the twisted-row character is usually independent of row number.

The ear, as well as the tassel, is indeterminate in its growth and continues to elongate at the tip (pl. 26, H, *t*), but many of the flowers at the tip of the ear remain rudimentary (pl. 28, C, *t*). Since the spikelets arise in acropetal succession they are successively younger from the base to the tip of the ear (pl. 26, G and H).

Two flower initials are produced in each spikelet, but in most corn varieties only one flower is functional. In a few types like Country Gentleman sweet corn both flowers are functional.

The two flowers of the ear develop from an unequal division of the meristem of the spikelet just as was pointed out for the flowers of the tassel. The flower differentiating from the larger mass of meristem (the upper flower) takes precedence in its development over the one from the smaller mass of meristem (the lower flower). The larger flower is the functional flower in those types of corn that have only one functional pistillate flower per spikelet. In the types of corn having two functional pistillate flowers per spikelet, the larger flower is more advanced at every stage in its development than the smaller flower.

Anther initials are the first of the reproductive parts of the flower to differentiate (pl. 27, B, *an*). In the pistillate flower the anthers begin differentiation but usually remain small and non-functional. Under certain growth conditions and in the genetic-type anther ear, the anthers of the pistillate flower may attain full development. Anthers well enough developed to show the locules are shown in plate 27, G, *an,* and J, *an.*

The pistil initial develops from the apex of the growing point which is located between the anther initials (pl. 27, B, *p,* and I, *p*). Development begins with the formation of a ridge, the silk initial, which partly encircles the tip of the growing point (pl. 27, C, *s,* and D, *s*). The ovule differentiates from the meristem which is partly enclosed by the developing silk initial (pl. 27, C, *ov,* and E, *ov*). The margin of the silk initial grows more rapidly on one side than on the other (pl. 27, E, *s*). Soon two distinct points appear (pl. 27, F and G) which continue to elongate (pl. 27, G and K) and which finally result in the biparted tip of the mature silk (pl. 28, E). Unequal growth rates of the margins of the silk initial result in the development of a tube-like structure partly enclosing the ovule (pl. 27, E, *ov*). The opening above the ovule gradually closes and becomes the stylar canal (pl. 27, G, *sc;* H, *sc;* and K, *sc*). As the silk elongates it becomes covered with hairs, the structure of which has been described by Weatherwax (1917) and Miller (1919). Hairs are just beginning to appear as fine points upon the silk in plate 27, K, *s,* and L, *s,* and they are shown, fully developed, with pollen grains germinating upon them, in plate 28, E, F, and G. The ovary is shown in plate 28, D, *o,* with the silk attached and partly enclosed by the flowering glumes. At this stage of pistil development all of the external parts have differentiated but the pistil has not attained full size. Silks begin to develop first at the base of the ear (pl. 28, A), and at the later stages of ear development a marked contrast in the length of the silks at the tip and the base of the ear can be seen (pl. 28, C).

An enlargement of a section of the ear at the same stage of development as in plate 28, A, is shown in plate 28, B, in which the attachment of the spikelets, variation in the length of the silks, and the size of the stylar canal can all be seen.

Very soon after pollen grains lodge upon the silk they germinate, and the pollen tube grows down the hair into the silk (pl. 28, F and G). This process has been described by Miller (1919) and Randolph (1936).

DEVIATIONS FROM NORMAL FLOWER DEVELOPMENT

Two deviations from normal flower development will be illustrated and described. The first is the development of two fertile flowers in a pistillate spikelet and the second is the development of pistillate spikelets in the tassel. Illustrations for the first deviation were taken from Country Gentleman sweet corn and are shown in plate 27, I, J, L, and M. Illustrations for the second deviation were taken from Golden Cross Bantam and are shown in plate 29.

It will be recalled that in those types of corn that have only one fertile flower per spikelet, the sterile flower begins but does not complete its development. The sterile flower develops from the smaller of the two divisions of the growing point of the spikelet initial. Anther initials and the pistil initial of the sterile flower differentiate (pl. 27, G, fl_2) but do not complete their development (pl. 27, H, fl_2). The pistil of the fertile flower develops as has been described, but the anthers do not, so that in examining a spikelet of the ear of those types of corn having one fertile flower per spikelet, all that can be seen after the silk has begun to elongate are the empty glumes (pl. 27, K, *e*) and the silk of the fertile flower extending beyond them (pl. 27, K, *s*).

When two fertile flowers develop in a pistillate spikelet each flower goes through the same sequence of development that has been described, but the rates of development are different. The upper flower arising from the larger of the two divisions of the growing point develops more rapidly than the lower flower. This was also pointed out for the development of the two flowers of the spikelet in the tassel. The differences in rates of development of the upper and lower flowers can be seen by comparing the upper flower in plate 27 (I, fl_1; J, fl_1; L, fl_1; and M, fl_1), with the lower flower (fl_2). While the upper flower develops first, the lower flower gradually overtakes the upper flower as the ear approaches maturity, but a difference in the development of the silks persists so that the silks of the two flowers do not emerge at the same time.

Paired grains of corn result when two fertile flowers are produced per spikelet. The germ of the upper flower faces the tip of the ear and the germ of the lower flower faces the base of the ear, resulting in the kernels being placed back to back. With the development of two grains per spikelet the kernels may be crowded out of line so that there are irregular rows or a lack of rows as shown in Country Gentleman sweet corn. Development of paired grains, according to Randolph (1936), was first described in pod corn by Sturtevant (1894), and Kempton (1913) was the first to interpret correctly the development of paired grains as being the result of the development of two fertile flowers per spikelet. Weatherwax (1925), Stratton (1923), and others have also described the development of double kernels.

The development of pistillate spikelets in the tassel is an interesting deviation from normal development. Kempton (1913) has pointed out that if there are pistillate flowers in the staminate inflorescence, it is the upper flower of the sessile spikelet that is pistillate and both of the flowers of the pediceled spikelet are staminate (pl. 29, A). Spikelet differentiation and the first stages in the development of the flowers are the same in both the staminate and the pistillate spikelets of the tassel. The essential difference lies in the degree of development of the anthers and pistils. In the pistillate flowers both the anthers and the pistil differentiate but the pistil takes precedence in development; in the staminate flowers both the anthers and pistil differentiate but the anthers develop instead of the pistil.

In most corn varieties only one flower, the upper one, of the spikelets of the ear is fertile, and the same is true of the pistillate spikelet produced in the tassel (pl. 29, B). Consistent with the development of the flowers of the ear of this type, the upper flower (pl. 29, A, fl_1, and C, fl_1) developed and the lower flower was abortive (pl. 29, A, fl_2, and C, fl_2'). Pistil differentiation and development were the same as previously described for the pistillate flower of the ear. The various stages in the development of the silk are shown in plate 29, A, *s*, to F, *s*, inclusive, and it can be seen that they are essentially the same as already described.

The development of the flowers of the staminate spikelet shows no deviation from normal development except that the pistil is a little further developed than in the tassels having only staminate spikelets. But the example shown in plate 29, A, *x*, should not, perhaps, be considered as typical because even in those plants that did not have pistillate spikelets, a considerably greater degree of pistil development was noted (pl. 25, F, *p*, and H, *p*) than would be expected in plants grown in the field. However, this is what should be expected of corn plants grown in the greenhouse under certain conditions of temperature and light.

EAR TYPES

Tassels and ears of four different ear types at early stages in their development are shown in plate 30. They are: four-row, Longfellow flint, ramosa or branched ear, and fasciated. These ear types are of interest because they deviate from the normal ear type of commercial corn.

In corn with four-rowed ears the spikelets on the central axis of the tassel and on the ear are in two ranks (pl. 30, D and H). The tissue between the ranks of spikelets develops into the cob. Ears of the four-rowed type used in this study varied (pl. 30, E) in the number of rows of spikelets per rank and sometimes there was a mixture of two and three rows of spikelets in the same rank. Some of the four-rowed plants developed four ranks of spikelets. They were eight-rowed like Longfellow flint.

The spikelets on the ear and central axis of the tassel of Longfellow flint are in four ranks (pl. 30, A, B). This gives the ear or tassel, in its early stages of development, the appearance of being square. The ear and central axis of the tassel are long, slender, and sharply pointed at the tip. The four-ranked appearance of the central axis of the tassel and of the ear is the result of the position of the spikelets (Brown and Anderson, 1947). In the tassel there are two pairs of spikelets opposite each other at a node. At any node the spikelets are at right angles to the spikelets immediately below and immediately above and this arrangement gives the four-ranked appearance.

A ramosa ear resembles a tassel in all of its morphological characteristics (pl. 30, I, J). It has a central axis and lateral branches arising from it. Collins (1917) has described how the ramosa tassel differs from that of normal corn, as follows: "In the Z. *ramosa* tassel the branches are more numerous and gradually decrease in size from the base upward, the transition from branches to pairs of spikelets being imperceptibly gradual." The same is true for the ear as can be seen in plate 30, I and J. In Z. *ramosa* the homology between the ear and tassel can be clearly seen because of the branching of both of the inflorescences. In normal corn, branching in the ear is suppressed but the tassel branches and therefore the ear and the tassel do not appear to be homologous.

Two fasciated types are shown in plate 30, Japanese Hull-less, and Mexican Long Kernel. At this stage of development, the ear and central axis of the tassel are short, thick, and blunt at the tip (pl. 30, C, F, and G). The similarity in the form of the central axis of the tassel and ear is clearly seen at this stage of development of Japanese Hull-less. The Mexican Long Kernel ear has a triparted tip. Other types of fasciated ears may be bi-parted, hollowed out, or flattened at the tip.

Anderson (1944) pointed out the correlation between condensation of the spikelets in the basalmost branch of the tassel and row number of the ear. He also stated that there is a correlation between the portion of the tassel branch that is condensed and the type of fasciation in the ear and the part of the ear that will be fasciated. The tassel of Japanese Hull-less illustrated here is too young to show this correlation. Older tassels of other fasciated types have been studied and they do show condensation of the spikelets. At very early stages of tassel and ear development the short, thick, blunt axis is a good indication of fasciation, and also of a high kernel row number.

SUMMARY

1. The developmental morphology of the tassel, ear, and their parts was studied by dissecting them from the corn plant at different stages in their development. Photomicrographs were taken of the various stages.
2. From germination to the dehiscence of the anthers, the shoot of the corn plant passes through two stages of development. In the first stage, leaves and axillary shoots are produced and the growing points of the main stem and axillary shoots remain short and shaped like a half sphere. In the second stage the growing points of the shoots and the internodes elongate and the tassel, ear, and their parts differentiate and develop.
3. Tassel and ear differentiation begins with the appearance of lateral projections, branch initials, which arise acropetally from the growing points. The branch initials at the base of the tassel elongate but the remainder on the central axis of the tassel and those which arise on the tassel branches differentiate into spikelet initials. All the branch initials of the ear of normal corn remain short

and differentiate into spikelet initials. Ramosa ear behaves like a tassel.

4. In both the tassel and ear the spikelet-forming branch initials divide into two unequal parts to form the spikelet initials which in turn divide into two unequal parts to form the flower initials. In the tassel the spikelet developing from the larger initial is pediceled and is ahead in development of the spikelet developing from the smaller initial, which is sessile. Likewise, the upper flower developing from the larger division of the pistillate spikelet is ahead of and larger than the lower flower developing from the smaller division of the pistillate spikelet.
5. In the ear the difference in the size of the spikelets arising from the unequal division of the branch initial is not so marked as in the tassel. The flower developing from the larger, upper division of the spikelet is the fertile flower, and the smaller, lower division is the abortive flower in those types of corn having only one fertile flower per spikelet. In those types of corn having two fertile flowers per spikelet the upper flower is larger and ahead of the lower flower in development.
6. Flower parts differentiate in the following order: empty glumes, flowering glumes, anthers, and pistil. In the pistil the order of development is ovary, silk, and hairs on the silk.
7. Four-row, ramosa, and fasciated are ear types that differ from the normal, and each type is described.

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Explanation of Plate

PLATE 24

Showing initiation and development of the tassel: *b*, branch initial from which spikelets differentiate; b_1, basal branch of the first order; b_2, branch of the second order; *e*, empty glumes; *gp*, growing point; *gp′*, growing point of the spikelet; *l*, leaf initial; *si*, spikelet initial; *t*, undifferentiated tip of an axis.

A—Growing point of a corn plant having four leaves visible, × 22.

B—Beginning of the elongation of the growing point just before tassel differentiation, × 22.

C and D—Differentiation of the branch initials of the tassel, × 22.

E—Elongation of the basal branches of the tassel, × 22.

F—Beginning of the differentiation of the spikelet initials on the central axis of the tassel, × 22.

G—A stage similar to F with some of the basal branches removed to show spikelet differentiation on the central axis, × 22.

H—Differentiation of spikelets and empty glumes on a portion of the central axis of the tassel, × 35.

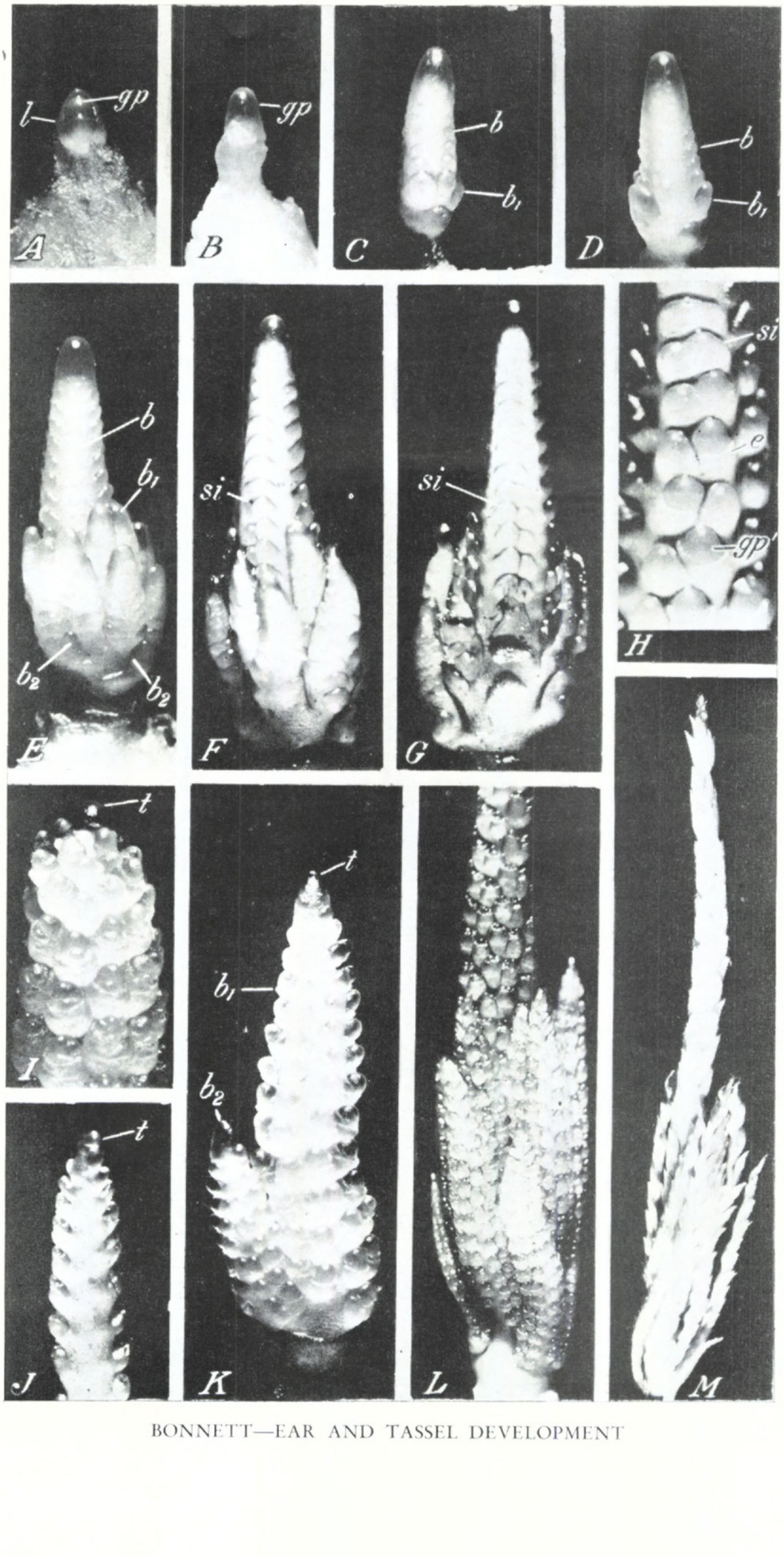
I—Portion of the tip of the central axis of the tassel, × 25.

J—Adaxial side of a branch of the tassel, × 22.

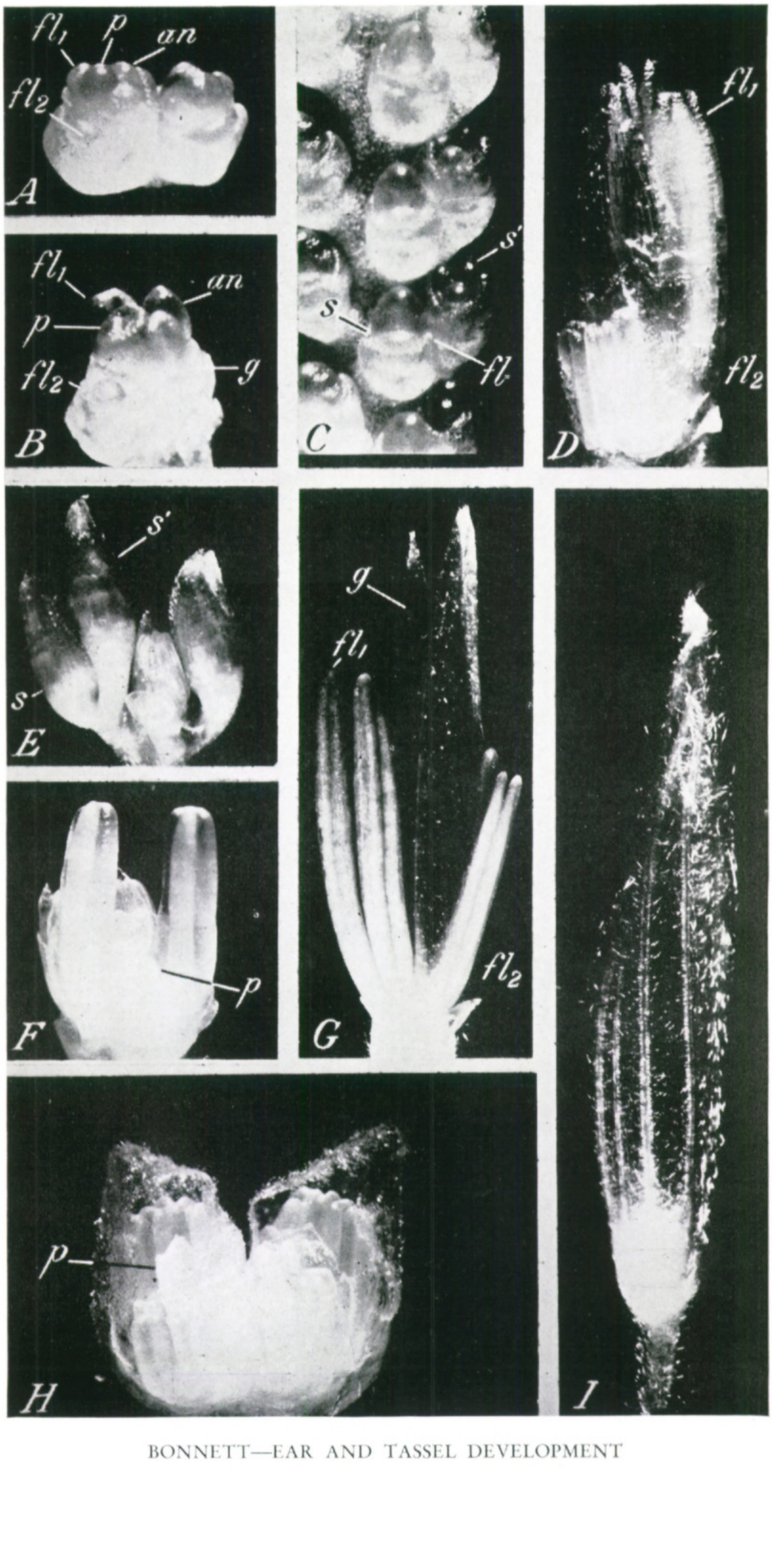
K—Abaxial side of tassel branches of the first and second orders, × 25.

L—A more advanced stage of tassel development, × 22.

M—Fully differentiated but not full-sized tassel, × 8.



BONNETT—EAR AND TASSEL DEVELOPMENT



BONNETT—EAR AND TASSEL DEVELOPMENT

Explanation of Plate

PLATE 25

All figures represent spikelet development in the tassel: *an*, anther; *fl*, flower initial; fl_1, upper flower; fl_2, lower flower; *g*, palea; *p*, pistil; *s*, sessile spikelet; *s′*, pediceled spikelet.

A—A pair of spikelets of the tassel at the beginning of the development of the flower parts. The upper flower, fl_1, is more advanced than fl_2, and the spikelet on the left, pediceled spikelet, is more advanced than the spikelet on the right, sessile spikelet, × 56.

B—Two flowers of a spikelet of the tassel showing the more advanced stage of the upper flower, fl_1.

C—Part of a branch of the tassel showing a more advanced stage of development of the pediceled spikelet, × 40.

D—Staminate spikelet with the empty glumes removed to show the difference in the size of the anthers of the upper and lower flower, × 20.

E—Two pairs of spikelets—one member of each pair is pediceled and the other sessile; the empty glumes have been removed from one spikelet, × 25.

F—Staminate flower with one anther removed to show the partly developed pistil, × 20.

G—Later stage of spikelet development in which the anthers of the lower flower are approaching the size of those of the upper flower, × 10.

H—A pair of spikelets both sessile, × 28.

I—A fully differentiated spikelet, × 10.

EXPLANATION OF PLATE

PLATE 26

Development of the ear: *b*, branch initial from which spikelet initials differentiate; *e*, empty glumes; *l*, leaf fundament; *pr*, prophyllum; *si*, spikelet initial; *s*, silk initial; *t*, undifferentiated tip of the ear.

A—Axillary shoot in which the ear develops, enclosed in the prophyllum, × 13.

B—Side view of the axillary shoot, × 17.

C—Beginning of the differentiation of the ear, × 25.

D—A more-advanced stage of ear development showing the formation of branch initials, × 25.

E—Beginning of spikelet differentiation by an unequal division of the branch initials, × 22.

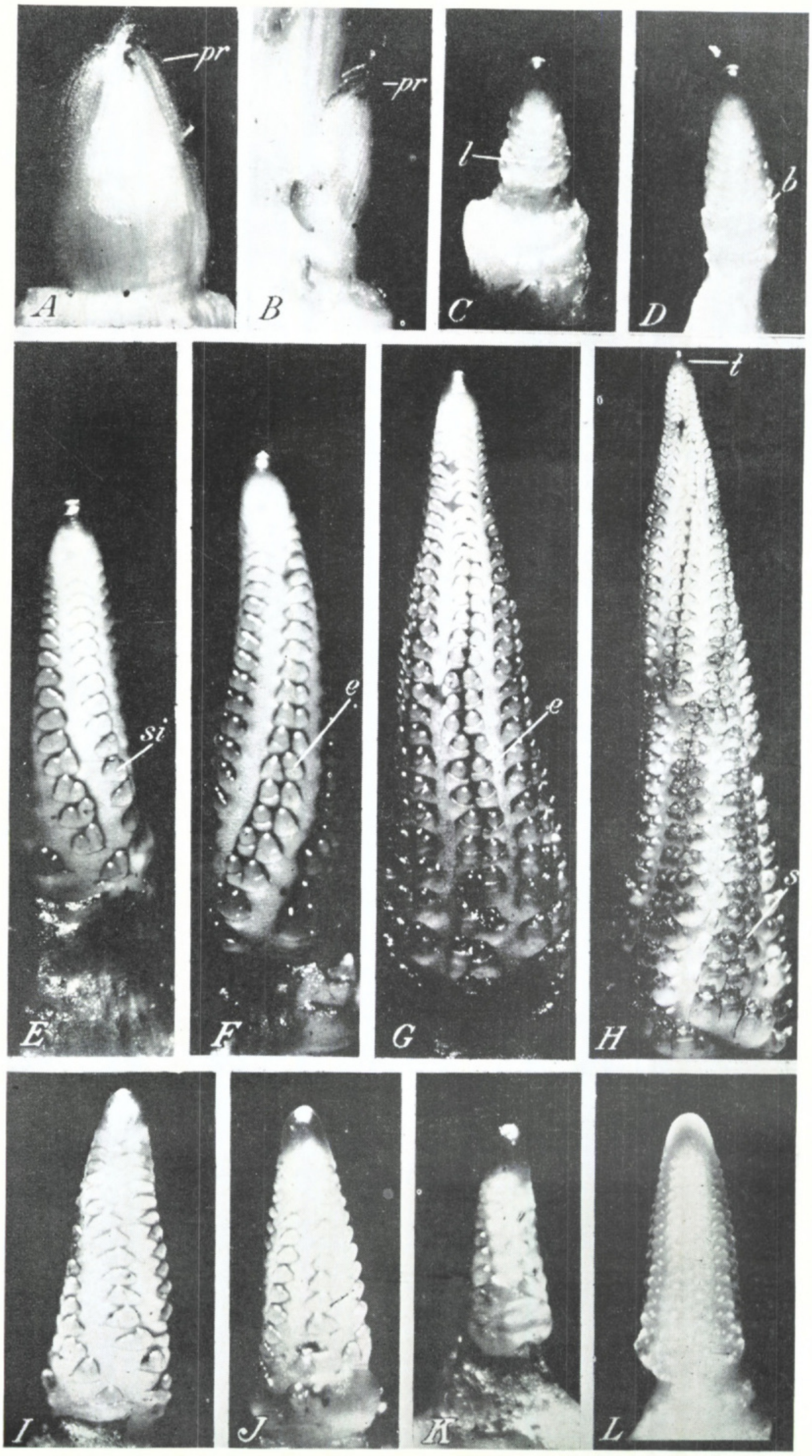
F—Development of the empty glumes as ridges on the growing point, × 22.

G—Paired rows of spikelets of the ear and, a more advanced stage, the development of the empty glumes, × 17.

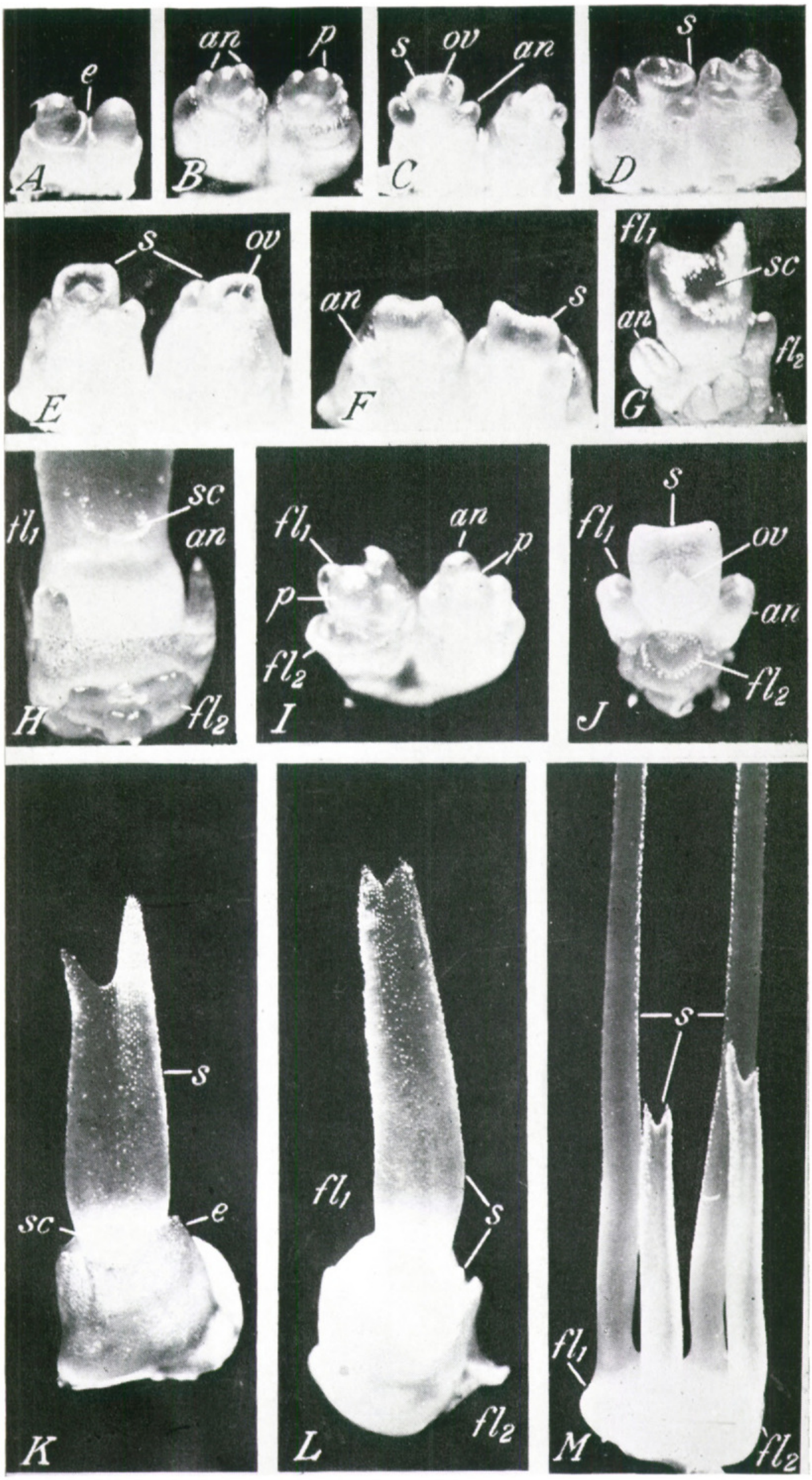
H—The differentiation and development of the silks can be seen at the base of the ear and an irregularity in the rows half way between the tip and butt, × 17.

I, J, and K—Topmost, second and third ears, respectively. All × 22.

L—Young ear of Country Gentleman sweet corn, × 17.



BONNETT—EAR AND TASSEL DEVELOPMENT



BONNETT—EAR AND TASSEL DEVELOPMENT