The development and structure of the vegetative and reproductive organs of kudzu, Pueraria thunbergiana (Sieb and Zucc) Benth

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THE DEVELOPMENT AND STRUCTURE
OF THE VEGETATIVE AND REPRODUCTIVE ORGANS OF KUDZU,
PUERARIA THUNDERGIANA (SIEB. AND ZUCC.) BENTH.

by

Harry Josef Romm

A Thesis Submitted to the Graduate Faculty
for the Degree of
DOCTOR OF PHILOSOPHY
Major Subject: Plant Morphology

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Iowa State College
1946
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>2</td>
</tr>
<tr>
<td>MATERIALS AND METHODS</td>
<td>4</td>
</tr>
<tr>
<td>GROSS MORPHOLOGY</td>
<td>5</td>
</tr>
<tr>
<td>ANATOMY AND CYTOLOGY</td>
<td>11</td>
</tr>
<tr>
<td>The stem</td>
<td>11</td>
</tr>
<tr>
<td>The leaf</td>
<td>12</td>
</tr>
<tr>
<td>The root</td>
<td>12</td>
</tr>
<tr>
<td>The flower</td>
<td>14</td>
</tr>
<tr>
<td>The seed</td>
<td>17</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>21</td>
</tr>
<tr>
<td>SUMMARY</td>
<td>25</td>
</tr>
<tr>
<td>LITERATURE CITED</td>
<td>27</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>32</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>33</td>
</tr>
</tbody>
</table>
INTRODUCTION

The kudzu bean, *Pueraria thunbergiana* (Sieb. and Zucc.) Benth., is a member of the Leguminosae. It is a vigorous, woody perennial vine, with large trifoliate leaves and reddish-purple flowers. It is a valuable forage crop, used in rotation for soil improvement and for erosion control in gullies and on hillsides, especially in the southern states. The plant is used also as an ornamental.

Kudzu is native to Japan and China. It was first introduced in the United States from the Orient in 1876, when it was exhibited at the Philadelphia Centennial. Recent studies by McKee and Stephens (27) have shown that it thrives best in the humid southeastern states. It has been grown, however, to some extent in the East, Southwest, Midwest, and Far West, but it is best adapted to states south of Virginia and Kentucky.

The present study of the development and structure of the vegetative and reproductive organs was undertaken to furnish a basis for studies in breeding, cultivation, and utilization of kudzu.
REVIEW OF LITERATURE

Avetta (2) published an extensive paper on the anatomy of the kudzu bean, dealing primarily with tissue systems rather than with cellular details of tissues. However, he described the wood-parenchyma as consisting of thin-walled and unlignified cells. Debold (14) studied 300 species of the tribe Phaseolae, seeking anatomical criteria for the differentiation of species, and he noted a number of characteristics of the kudzu bean. He described the leaves as typically papillose or sub-papillose on the lower epidermis. He also observed tannin sacs in the pith and bast. Solereder (36) described some features of the anatomy of the kudzu, particularly the origin of cork in the second to sixth subepidermal cell layers. Avetta used the specific term thumbergiana Benth., but the writer is using the spelling thunbergiana (Sieb. and Zucc.) Benth. as used by Engler and Prantl (16).

Burkart (6) reported that the tuberous roots, from which starch is obtained, develop from adventitious roots. Tabor (40) studied the seedlings and found that they have several advantages over "crowns" for propagation. The seedlings can be produced in one growing season, the yield per acre is higher, and the lifting, storage, transportation, and planting are less difficult than with "crowns". He observed that the hypocotyl
of young seedlings is more limited in its ability to elongate than in other leguminous field crops. Tabor (39) studied seed production in Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi and noted that vines growing over bushes, trees, fences, or vertical supports produced seeds most abundantly. Poorly seeding plants had few pods, and also few seeds per pod. The best seeding plants had ten to twelve seeds per pod and twenty to thirty pods per cluster.

Within the past few years, agronomic studies have been made in the United States, South Africa, Cuba, Australia and many other countries to determine the economic value of the kudzu bean. Degener (15) found that "ko-pu" fiber can be prepared from the bark of the young shoots of the kudzu. When the fiber is of good quality, it is made into cloth from which the Chinese make summer underwear. Pierre and Bertram (31) found that increasing the number of cuttings of kudzu reduces its production of food reserves. Tabor (38) and Arnold (1) studied the cultivation of kudzu; Bailey (3), Brink (4), Cates (9), and Swabey (37) emphasized its value for erosion control; McKee and Stephens (27), Calvino (7), McMartin (28) Pieters (32, 33), and Tracy (41), investigated its value as a forage crop.
MATERIALS AND METHODS

The plants used in this study were obtained from an eroded bank along a stream which flows through the truck garden of Tuskegee Institute, Tuskegee, Alabama. The plants were between eight and ten years old and had been grown from transplants.

Seeds were obtained through the courtesy of Dr. Roland McKee and Dr. M. F. Spaulding, who made the collections in the vicinities of Beltsville, Maryland and Tuskegee Institute, Tuskegee, Alabama, respectively. The seeds were prepared for germination by soaking in concentrated sulphuric acid for twenty or thirty minutes as recommended by McKee and Stephens and then thoroughly washed in tap water.

For cytological studies, root tips and pollen mother cells were killed in variations of the Nawaihin (Craf) formula and embedded in paraffin. Sections were stained in gentian violet-iodine or hematoxylin. Buds were also fixed in Cernoy's solution for acetocarmine smears.
GROSS MORPHOLOGY

Kudzu is a coarse, hairy, stoloniferous vine. The stems, which may attain a length of more than seventy feet during a growing season, are prostrate or climbing over brush, shrubs, trees, fences or other support. The cylindrical stems are less than a centimeter in diameter (Fig. 1). When the stems are in direct contact with moist soil rooting occurs at the nodes (Fig. 2). The seedling stem is upright for about two to three inches above the ground and then bends at an angle of almost ninety degrees. Most of the stem is thus prostrate on the ground or climbs over brush or other support. In cross section the stems are almost cylindrical and are pubescent.

The leaves are alternate, trifoliate compound with the lateral leaflets ranging from 80 mm. to 106 mm. in width, and from 122 mm. to 150 mm. in length. The median leaflet ranges from 55 mm. to 70 mm. in width and from 121 mm. to 209 mm. in length (Fig. 1 - 3). The length of the petioles ranges from 3/4 inch near the free end to 9-3/4 inches near the basal end. The petiole is enlarged at the base for a distance of 5 mm., forming a definite pulvinus. Just above the pulvinus, the petiole is rounded in cross section, except for a groove on the ventral surface. Each leaflet of the compound leaf has a short petiole. The margins of the leaflets are entire. The petiole is also
enlarged forming a pulvinus at the distal end. The venation is of the netted type, with three principal veins in each leaflet. Membranous stipules are present at the bases of both the simple and compound leaves. Those at the base of the compound leaves are ovate and acute.

Observations were made on the movements of the leaves of kudzu plants growing in pots and in the field. Bending occurs at the pulvinus at the base of the petiole and at the pulvinus at the base of each leaflet. The petioles begin to rise to the erect position from 7 a.m. to 3 p.m. and begin to fall from 3 p.m. to 7 p.m. About 1 p.m. the lateral leaflets bend so that their faces almost touch. The terminal leaflet bends so that its surface touches the vertical edges of the lateral leaflets.

The root system of kudzu consists at first of a tap-root which develops from the primary root of the seedling. Adventitious roots arise from stolons when they are in direct contact with moist soil. In very young seedlings the primary root is thread-like, and penetrates the soil several inches before the plant develops its first leaves.

Flowers appear approximately on July 17 at Tuskegee Institute, Tuskegee, Alabama. The inflorescence is an axillary raceme, commonly located near the ends of runners (Fig. 4). The flowers are pedicelled, arranged alternately, usually three flowers at each node (Fig. 5). The number varies from a few to well over three hundred. The peduncles and pedicels are pubescent.
The pedicels are approximately as long as the calyx. The calyx is subtended by two lanceolate bractlets about one-fourth inch long. Its lobes are longer than the tube and are lanceolate. The basal lobe is somewhat longer and narrower than the others (Fig. 6). The calyx tube is dark red-purple and is covered with long, dense tan-colored hairs. The corolla consists of five reddish-purple petals which are irregular in shape. The upper petal (standard) is broad and upright, and measures about 15 mm. in length and 11 mm. in width. The claw of the standard is about 3 mm. in length and 1 mm. in width.

The two lateral petals (wings) are borne one on either side of the standard. They consist of a blade, about 10 mm. in length and .50 mm. in width. The claw is about 5 mm. long, and .50 mm. wide.

Each keel petal consists of a blade and a claw; the blade is about 12 mm. long and 6 mm. wide, while the claw measures about 5 mm. in length and .50 mm. in width.

The ten stamens are of unequal length. Nine of the filaments are fused and form a tube around the pistil. The filaments are attached to the backs of the anthers. The anthers are about 1 mm. long and about .40 mm. wide. The pollen grains are isodiametric and are relatively rough.

The pistil is about 19 mm. long and consists of a single carpel. The ovary is about 5 mm. long and 1 mm. thick. It is green and has long, white hairs. The style curves and tapers
at the apex. It is equally as long as the ovary. Nectaries are located at the base of the staminal tube on either side of the free stamen.

The formation of pollen takes place very early in the flower and the anthers dehisce while the corolla is closed. Anthesis progresses from the base of the inflorescence toward the apex and requires twenty-one to thirty days for completion. The flowers of the kudzu are adapted for cross-pollination by honey bees and bumble bees.

The pods number from ten to thirty per inflorescence. They are yellow-green in color, with numerous long, reddish-brown hairs (Fig. 5). The pods are 5 to 8 cm. long and about 1 cm. wide. Each pod has from three to ten seeds.

The seeds are kidney-shaped and average about 3 mm. in length and 2 mm. in width. The surface of the testa is lustrous and usually reddish-brown or gray with black specks. In the center of the concave surface there is a depression .50 mm. in length and white in color, bordered by a raised margin.

The seeds of kudzu have a hard and impermeable seed coat. In this study the seeds were soaked in concentrated sulphuric acid for 20 to 30 minutes to render the coat permeable. The seeds were then thoroughly washed in tap water and soaked in tap water over night. After this treatment the seeds germinated in less than twelve hours.

When placed in water after the acid treatment the reddish-brown seeds absorbed water very quickly whereas the speckled
gray seeds may remain in water thirty-six hours or longer before showing signs of germination.

The relatively large seedling has two green, opposite, epigeal cotyledons. The hypocotyl is long and merges gradually into the primary root (Fig. 7). Unlike the clovers, the seed coat is not carried on the tip of the cotyledons but remains in the soil. Their glabrous surfaces are fleshy, and somewhat elliptical. The cotyledons measure about 8.5 mm. in length and about 4.5 mm. in width. Their petioles are broad and united at their bases to form the cotyledonary sheath.

The hypocotyl varies greatly in length, and is about .5 mm. in diameter. It is slightly swollen near the collet, the region of transition between the root and the hypocotyledonary structures.

The primary root is much smaller in diameter than the hypocotyl. Lateral rootlets develop very early during the growth of the seedling and by the time the plumule appears between the cotyledons, at least two rows of rootlets can be distinguished; by the time the second compound leaf appears, three rows of rootlets have developed.

Growth of the plumule is very rapid. The cotyledons enlarge during the first two days. The first leaves are opposite and simple, and they appear eight days after the cotyledons become divergent. The lamina is entire, acuminate, slightly concordate, about 7 mm. in length, and 6 mm. in width. These
leaves and their petioles are pubescent. Successive leaves are alternate, trifoliate compound and pubescent. They unfold on the 11th, 16th, 25th, 30th, and 55th days.
ANATOMY AND CYTOLOGY

The stem

The histogens of the stem apex consist of a tunica of two layers of cells, in which planes of cell division are mostly anticlinal, and a corpus of many cells. The planes of cell division in the corpus are at random.

The epidermal cells of the stem are oval in section and covered with a cuticle. The cortex has several layers of collenchyma, which are especially thick in the region of the larger bundles. There are several layers of chlorenchyma. The endodermis is a single layer of large, elongated cells, recognisable by their starch content. The pericycle is a band of sclerenchyma, consisting of three to four layers of compactly arranged, thick-walled, polygonal cells.

The vascular bundle is of the collateral type (Fig. 89). The phloem consists of sieve tubes, companion cells and parenchyma. Secondary xylem consists of large vessels, numerous small, thick-walled tracheids, and considerable parenchyma. Cork appears rather early on stems in the kudzu. Just below the epidermis a layer of cells becomes meristematic and initiates periderm. The cork cambium of the periderm produces derivatives which become cork cells. The inner derivatives remain alive and compose the parenchymatous phelloderm or secondary cortex. In
a section of a month old hypocotyl there is evidence of the bark being sloughed off. In a mature stem the vascular cambium has several layers of cork.

The leaf

The upper and lower epidermal layers of the kudzu leaf are composed of closely fitted rectangular cells ranging from 4 to 15 microns in length and 4 to 7 microns in width. The walls of the cells are relatively thick. In the region of the midrib the walls are considerably reinforced. The cuticle over the upper epidermis is as thick as that over the lower epidermis. Although stomates are abundant on both surfaces of the blade, they are more numerous on the undersurface.

The rows of slender palisade cells are found in the simple leaf as well as in the compound leaves. The palisade tissue makes up about half of the thickness of the mesophyll. The spongy parenchyma consists of two layers of cells. Numerous intercellular spaces occur, especially in the spongy zone (Figs. 10, 11).

The vascular bundle in the midrib is collateral. Mechanical tissue is present on both the ventral and dorsal sides. The phloem is present in strands on the dorsal side. The vascular bundle of the midrib has a cambium and some secondary tissue. The small veinlets exhibit no secondary growth.
The root

A longitudinal section of the apex of the radical a few hours after germination shows a root cap, dermatogen, periblem and plerome. The root tip has the "open type" or "pisum type" of promeristem, in which a broad transverse initiating zone produces the root cap and the primary tissue systems of the root. Fericlinal division in the cortical derivatives of the initiating zone determines the thickness of the cortex. As the inner region of the periblem ceases cell division, the endodermis becomes differentiated.

The primary root has an exarch, tetrarch stele (Fig. 12). The protophloem elements and the first xylem cells differentiate simultaneously. The pericycle and the endodermis are well differentiated by the time the protophloem becomes distinct. Four groups of primary phloem fibers differentiate early in the development of the root.

The large late protoxylem cells differentiate rapidly and develop closely arranged spiral thickenings. There is considerable parenchyma between the xylem and the phloem strands.

As the metaphloem develops, metaxylem also becomes differentiated. The cells of the metaphloem are much larger in diameter than in the protophloem. The diameter of the metaxylem cells is also much larger than the protoxylem cells. The increase in size of the metaxylem cells of the vascular cylinder is responsible for the crushing of the protophloem cells which lie between the pericycle and the fibers.
In the mature root most of the tissue is secondary xylem. The phloem and secondary cortex comprise a narrow zone. The tracheids and the vessels are arranged in rows. Parenchyma occurs near the vessels and among the tracheids. The secondary phloem consists of sieve tubes, companion cells, and very little parenchyma.

Periderm develops early in the root. The secondary cortex is limited by a cork cambium and five or six layers of cells. The activity of the cork cambium produces and adds parenchymatous cells to the cortex. The vascular cambium produces a zone of phloem. External to the secondary phloem is a zone of phelloderm derived from the cork cambium.

A short time after differentiation of the primary permanent tissues of the root, secondary roots are initiated. They arise endogenously from meristematic cells of the pericycle. Adventitious roots are very common on the lower part of the hypocotyl. Their structure is similar to the secondary roots. They arise opposite one of the four groups of protoxylem cells. In the hypocotyl the vascular pattern is endarch.

The flower

The flower arises as a dome-shaped primordium in the axil of a bract. The first perianth whorl to appear is the calyx which consists at first of five separate lobes but which later becomes gamosepalous (Fig. 15). Very early in ontogeny, the
calyx arches over the primordia of the other floral structures. At anthesis the calyx consists of a tube terminated by four relatively long, acuminate lobes; one of the lobes consists of two fused members.

The petal primordia alternate with the lobes of the calyx. The keel petals develop first, wing petals next, and the standard last (Fig. 14). The stamens appear soon after the initiation of petal primordia. Stamens are in one cycle but five develop in advance of the other five. The pollen mother cells in the earlier set are in the pollen quartet stage when those in the later set are in the metaphase of meiosis. The filaments of all ten stamens are free a few millimeters below the anthers, but below this point nine of them are fused into the staminal tube, whereas the tenth stamen remains free its entire length.

The anthers are at first cylindrical and consist of homogeneous meristematic tissue, but soon they become four lobed. The development of the anthers in the kudzu follows the course generally described in Leguminosae. Hypodermal cells undergo periclinal divisions producing a parietal layer and the arche- sporial initials. The parietal cells undergo a second division, the outer daughter cells becoming part of the wall tissue and the inner layer becoming the tapetum. At this stage of development the cells of the tapetum are much larger than the arche- sporial cells. The anther wall finally consists of an epidermis
and a zone of two or three parenchymatous cells. The archesporial cells produce the column of microsporocytes by several somatic divisions.

Prior to meiosis the sporocytes are polyhedral (Fig. 15, 16). They have uniformly dense cytoplasm and a large nucleus which commonly contains one prominent nucleolus. The remainder of the chromatin in this species is too obscure for the study of meiotic details. Two divisions of meiosis produce the pollen quartets. By a process of furrowing inward from the periphery of the mother cell, the microspores are delimited (Figs. 17 - 20). Mature pollen grains are spherical and are relatively rough.

The haploid number of chromosomes is eleven. Counts were made in the polar views of the metaphase in the root tips and in anthers.

The carpel arises at the apex of the floral axis as a dome-shaped primordium. It is open at the top and along the ventral surface as seen in cross section. The carpel margins become completely united before ovule formation.

The ovules arise as dome-shaped primordia along the inner margins of the ventral suture. The 9 to 13 ovules are alternately arranged in two rows. Many of the ovules abort. Growth of the ovules is most rapid on the basal side and consequently they curve toward the stylar end of the ovary and become campylotropous (Fig. 21).
Both integuments appear simultaneously (Fig. 22); the outer integument, however, grows somewhat more rapidly than the inner one and completely covers the micropylar end of the nucellus at the time of fertilization. The outer integument consists of three cell layers, except in the region of the micropyle where it becomes considerably thicker by periclinal divisions (Fig. 23).

As many as four sporogenous cells were observed in the young ovules, but usually only one is functional (Fig. 22, 23). The sporogenous cell functions directly as the megasporocyte, which undergoes meiotic divisions and produces a linear tetrad of megaspores. Three megaspores disintegrate, and the surviving chalazal megaspore gives rise to the eight nucleate female gametophyte, which consists of three ephemeral antipodals, two polar nuclei, the egg, and two synergids (Fig. 24).

The seed

Three to four days after fertilization the proembryo consists of a short, massive suspensor of several tiers of cells, and a terminal globular portion of fifty or more cells (Fig. 25). The endosperm immediately surrounding the embryo is cellular, whereas that farther away toward the chalazal end is still in the free nuclear condition. The nucellus is almost completely absorbed at the micropylar end and along the sides, and the embryo sac is in direct contact with the outer
integument. That portion of the nucellus remaining at the chalazal end shows evidence of being absorbed. The inner integument becomes reduced to one layer of cells along the sides of the ovule.

Organs of the embryo are discernible as early as ten days after fertilization. The buds in the axils of the cotyledons, the hypocotyl and the radicle are well defined (Fig. 27). The vascular strands in the hypocotyl are clearly recognizable. The embryo now occupies nearly all of the space within the integuments. However, the endosperm is limited to a thin layer of cells along the sides of the embryo sac, and it is considerably thicker at the micropylar and chalazal ends. The endosperm of the mature seed constitutes an unbroken covering of two to several cell layers in thickness around the embryo. The endosperm absorbs water readily and becomes swollen and somewhat mucilaginous.

The seed coat is almost entirely the product of the outer integument. The modifications associated with the transformation of the outer integument into the seed coat are first noticeable in its outer epidermal cells in the micropylar and chalazal regions. Immediately following fertilization the outer epidermal cells of the outer integument begin rapid radial elongation. They continue to elongate until their length in the region of the micropyle is approximately nine times their length at the time of fertilization. A similar elongation of
the epidermal cells takes place later along the sides of the developing seed, where their increase in length is ten times their length at the time of fertilization. These modified epidermal cells are known as the malpighian layer. This layer has no well defined cuticle and no domes or light line, and the lumen is greatly reduced. A thin cuticle develops after fertilization. The length of a fully mature malpighian cell is approximately four and one half times its width. The lateral walls are moderately thickened while the outer walls are very much thickened (Fig. 26).

Soon after the cells of the outer epidermis begin to form the malpighian layer, the subepidermal layer begins a series of modifications and becomes the osteosclereide layer. This layer consists of one row of I-shaped cells which are uniform in size and length. The osteosclereide layer envelops the seed except in the region of the hilum, where the cells undergo very little modification.

Immediately beneath the osteosclereide layer are several rows of cells which constitute the nutritive tissue. The cells of this tissue are irregular in shape, their walls are slightly thickened, and they contain chloroplasts.

Surrounding the hilum is an arillate rim, which may function to absorb water. In this same region, just opposite the micropyle, is a small, elongated depression known as the strophiule. Figure 28 is a radial section through the hilum. It is in this
region of the seed coat that the vascular bundles enter the seed from the funiculus. Water and minerals enter the seed through this vascular connection. Figure 29 is a section through the edge of the hilum showing a mass of reticulate-pitted sclerenchymatous cells below the hilum.
DISCUSSION

The hypocotyl varies in length as in white clover, in which Erith (17) reported that the length of the hypocotyl was influenced by the depth of planting, intensity of light and other external conditions.

The flowers of the kudzu develop essentially as in other Leguminosae. The sequence of emergence is sepals, petals, stamens, and pistil as reported by Guard (20) for Soja max, Payer (30) for Trifolium orchrolenum, Goebel (18) for Phaseolus, Grégoire (19) for Lathyrus, Trifolium and Lupinus, Westgate and Coe (42) for Trifolium and Coe and Martin (10) for Melilotus alba. Goebel reported this type of emergence as being characteristic of Leguminosae.

The appearance of the stamens in one cycle, five developing in advance of the others, was observed by Payer (30) in Trifolium orchrolenum, and Coe and Martin (10) in Melilotus alba and Melilotus officinalis.

The closure of the carpel margins occurs as described by Goebel (18) in Phaseolus and other legumes, Bugnon (5) in Lathyrus, Trifolium and Lupinus, Coe and Martin (10) in Melilotus alba, and Guard (20) in Soja max. Grégoire (19), however, did not find any distinct line between the carpellar margins in Lathyrus.
The number of rows in the nucellus is similar to the number found by Martin (25) in Trifolium (three species), and *Medicago sativa*. The destruction of the nucellus by the developing embryo sac in the kudzu differs from the condition found by Coe and Martin (10) in *Melilotus alba*, Reeves (35) in *Medicago sativa*, Young (43) in *Melilotus alba*, and others. These investigators reported a complete destruction of the nucellus over the micropylar end of the embryo sac by the time of fertilization.

The common occurrence of one sporogenous cell functioning directly as the megaspore mother cell was also reported by Reeves (35) in *Medicago sativa*, and by Young (43) in *Melilotus alba*. The occasional occurrence of more than one megasporocyte was reported by Reeves (35) in *Medicago sativa*, and Coe and Martin (10) in *Melilotus alba*. Héral (23) found an exception to this behavior in *Medicago arborea* in which the hypodermal cell was observed to form two daughter cells, of which the lower one is functional.

There is evidence that more than one megasporocyte may function. In a number of ovules of the kudzu, two embryo sacs, in the early stages of development, were observed. Martin (25) found that two rows of megaspores may occur in the same nucellus in *Medicago sativa*, and often more than one megaspore starts to form an embryo sac but usually not more than one mature embryo sac was found. However, Martin and Watt (26) reported the occurrence of two normal embryos in a seed of
Medicago sativa and Melilotus alba. Jönsson (24) also found more than one functional embryo sac in Trifolium pratense.

The early disappearance of antipodals in kudsu resembles the condition reported by Martin (25) in Trifolium (three species), Medicago sativa, and Vicia americana, and Coe and Martin (10) in Melilotus alba. In a more recent paper Reeves (35) noted a similar behavior in Medicago sativa. Guignard (21) found antipodals persisting after fertilization in Mimosoideae and Caesalpinioideae, but disappearing in Papilionoideae.

There are two malpighian layers in the region of the hilum in kudsu. Some investigators consider one row of the cells as belonging to the testa and the other row to the funiculus. Pammel (29), however, treated the two layers as a part of the testa.

The cells of the nutritive layer in the seed contain chloroplasts which equip them for food manufacture. Pammel (29) has showed in his study of Strophostyles pauciflora that the starch in the nutritive layer serves to nourish the growing seed.

The strophiole, which contains vascular strands, is in the region of the hilum opposite the micropyle. Through these vascular connections water and minerals reach the seed. In some hard seeds it has been demonstrated that water enters the interior of the seed through the strophiole in the initial
stage of germination as shown by Martin and Watts (26) for *Melilotus alba*.

The seed of kudzu has a sclerenchymatous mass of cells below the hilum, resembling the structure found in *Pisum sativum*, illustrated in Hayward’s figure 174 (22).
SUMMARY

The present study of the development and structure of the vegetative and reproductive organs of kudzu was undertaken to furnish a basis for studies in the breeding, cultivation and utilization of the plant.

Kudzu is a coarse, hairy, stoloniferous vine with alternate, trifoliate compound leaves, and racemose, papilionaceous flowers. Twenty to thirty days are required for the completion of anthesis in one raceme.

The order of initiation of floral organs is sepals, petals, stamens, and carpel.

The haploid number of chromosomes is eleven.

The ovules arise as dome-shaped primordia along the inner margins of the ventral suture. The nine to thirteen campylotropous ovules develop simultaneously, arranged alternately in two rows.

The sporogenous cell generally functions directly as the megasporocyte which undergoes meiotic divisions and produces a linear tetrad of megaspores. Three of the megaspores disintegrate, and the surviving chalazal megaspore gives rise to the female gametophyte.

The female gametophyte consists of two polars, an egg, and two synergids. The antipodals disappear before fertilization.
The nucellus soon becomes absorbed at the micropylar end and along the sides.

The proembryo has a short, massive suspensor of several tiers of cells. The mature embryo consists of two cotyledons, a simple leaf, a compound leaf and a large radicle.

The endosperm remaining when the seed is mature constitutes an unbroken covering of two to several cell layers in thickness around the embryo.

The seed coat is almost entirely the product of the outer integument. The malpighian layer has no well defined cuticularized layer, and no domes or light line. The osteosclereide layer consists of one row of I-shaped cells. The layer is continuous except in the region of the hilum. The nutritive layer contains chloroplasts.

An arillate rim surrounds the hilum. The strophiole is a small, elongated depression in the region of the hilum opposite the micropyle.
LITERATURE CITED


22. Hayward, H. E.

23. Bérald, J.

24. Jonsson, B.

25. Martin, J. N.

26. and Watt, J. R.

27. McKee, Roland and Stephens, J. L.

28. McMartin, H.

29. Pammel, L. H.

30. Payer, J. B.

31. Pierre, W. H. and Bertram, F. E.
32. Pieters, A. J.  

33.  

34. Piper, C. V.  

35. Reeves, R. G.  

36. Sorender, Hans  

37. Swabey, C.  

38. Tabor, Paul  

39.  

40.  

41. Tracy, S. M.  

42. Westgate, J. M. and Coe, H. S.  
43. Young, W. J.  
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PLATE I

Fig. 1. Terminal portion of stoloniferous stem.

Fig. 2. Adventitious roots at node in contact with moist soil.

Fig. 3. Alternate trifoliate leaves.

Fig. 4. Terminal portion of runner showing inflorescences in axils of trifoliate leaves.
PLATE II

Fig. 5. Arrangement of flowers in an inflorescence.

Fig. 6. Organs of dissected flower.

Fig. 7. Seedlings:

1. Seed.

2-4. Few hours after germination.

5. Seedling with cotyledons.


7. Seedling with first compound leaf.
PLATE III

Fig. 8. Diagram of stem showing tissue systems. x100.

Fig. 9. Detail of vascular bundle and adjacent tissues. x800.

Fig. 10. Diagram of leaf. x80.

Fig. 11. Detail of portion of leaf blade. x200.

Fig. 12. Diagram of root showing tissue systems. x100.

Fig. 13. Initiation of sepals. x900.

Fig. 14. Initiation of petals. x900.

Explanation of plate:  b, bract;  co, cortex;  e, epidermis;  en, endodermis;  h, hypodermis;  p, petal;  per, pericycle;  phl, phloem; s, sepal;  x, xylem.
PLATE IV

Fig. 15. Anther lobe showing archesporial cells. x900.

Fig. 16. Microsporocyte. x900.

Fig. 17. Diad. x 900.

Fig. 18. Early tetrad. x900.

Fig. 19-20. Tetrad showing progressive cleavage. x900.

Fig. 21. Longitudinal section of flower bud. x50.

Fig. 22. Longitudinal section of ovule showing megasporocyte and the initiation of integuments. x900.

Fig. 23. Ovule with closed integuments. x560.

Fig. 24. Female gametophyte showing antipodals, polars, synergids, egg and four rows of nucellar tissue. x900.

Fig. 25. Proembryo and a portion of the endosperm. x800.

Fig. 26. Seed coat showing cuticle over malpighian cells, lumen in each malpighian cell, I-shaped osteosclereides, and nutritive layer. x900.

Explanation of plate: c, cuticle; e, epidermis; ii, inner integument; lu, lumen; m, malpighian cell; n, nucellus; nu, nutritive layer; o, osteosclereides; ol, outer integument.
PLATE V

Fig. 27. Nearly mature embryo.

Fig. 28. Radial section through hilum showing arillate rim and strophiole.

Fig. 29. Section through edge of hilum showing mass of reticulate sclerenchymatous cells.