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JOURNAL OF AGRICULTURAL RESEARCH

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DEVELOPMENT OF AXILLARY BUDS ON FRUITING BRANCHES OF PIMA AND UPLAND COTTON [1]

By C. J. KING

Agronomist, Office of Cotton, Rubber, and Other Tropical Plants, Bureau of Plant Industry, United States Department of Agriculture

INTRODUCTION

The cotton plant produces two distinct types of branches, which occupy different positions and have different structures and functions. These are the upright "limbs" or vegetative branches, which do not produce flowers or bolls, and the fruiting branches, which assume horizontal positions and on which are developed the floral buds. Cook [2] has shown that in addition to the bud that serves to continue the growth of the shoot, each node of the main stalk produces two other buds, one in the axil of the leaf and another to the right or left of the axil, called an extra-axillary bud. The axillary buds usually remain dormant, but may be developed into vegetative branches when conditions for luxuriant growth are favorable. The fruiting branches arise from the extra-axillary buds on the main stalk and on vegetative branches.

The fruiting branches also produce two buds at each node, corresponding to the two types on the main stem. These are a flower bud, which appears between the bases of the stipules, and an axillary bud, which is formed in the axil of the leaf. It has been observed that the axillary buds on the fruiting branches of Egyptian cotton differ somewhat in morphology and behavior from those on the upland type. These distinctions and their possible relationship to cultural problems and studies in bud shedding are presented in this paper.

COMPARISON OF AXILLARY BUDS ON EGYPTIAN AND UPLAND COTTONS

Under ordinary conditions of growth a greater part of the axillary buds on the fruiting branches of upland cotton remain dormant, but in cases of exceptional luxuriance, or when the terminal growth of the branches or main stem is injured, a considerable number of them may undergo further development and produce short vegetative branches. (Fig. 1.) [3]

In Egyptian cotton the axillary buds on the fruiting branches seldom if ever remain dormant for any great length of time. They emerge from their positions in the axils of the leaves as minute triangular buds or "squares," about two or three days after the extra-axillary bud on the same node, and at first in all respects appear

[1] Received for publication July 17, 1930; issued November, 1930.

[2] COOK, O. F. MORPHOLOGY OF COTTON BRANCHES. U. S. Dept. Agr., Bur. Plant Indus. Circ. 109: 11-16, illus. 1913.

[3] The photographs illustrating this paper were made by H. F. Loomis.

like normal fruit buds. They are unlike the axillary buds of upland cotton in that they are usually unattended by a leaflet with stipules. (Fig. 2.) Under ordinary conditions their growth continues for only a few days, and then they drop off or begin to shrivel and finally dry up into minute dark-colored bodies, many of which remain attached to the fruiting branches.

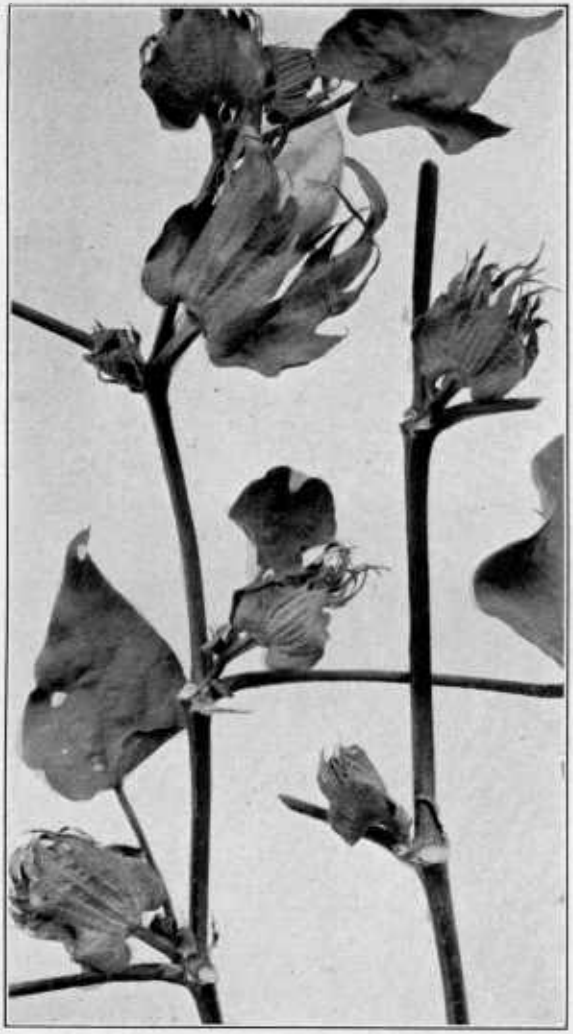

FIGURE 1.—A fruiting branch (in two sections) of Acala (upland) cotton, showing development of axillary buds at every node. This development occurred late in the season, long after the shedding of extra-axillary bolls on the first four nodes, whose positions are shown by the scars. At node 5 the largest bud shown is the extra-axillary, and the small bud to the left is the axillary. At node 6 only the extra-axillary bud is visible

If the plants are especially productive or if the terminal growth of branch or main stem is aborted or injured, a number of the axillary buds may continue development. When this occurs there usually is produced a single boll on a long stem (fig. 3), but occasionally two or more bolls may develop. Some of the boll stems have the appearance of simple pedicels, but many of them show some type of joint and occasionally small bract-like leaves or stipules, which indicate that the "pedicels" comprise shortened branches. Cook [4] points out that in reality three independent elements are represented in such stems — an axillary branch, a fertile branch from the axillary, and the pedicel of the boll, all fused into a simple stem. This type of fusion is carried much farther in Egyptian cotton than in upland cotton. In upland cotton the boll stems invariably have a well-defined joint to indicate that a branch is involved. (Fig. 4.)

[4] COOK, O. F. DIMORPHIC BRANCHES IN TROPICAL CROP PLANTS: COTTON, COFFEE, CACAO, THE CENTRAL AMERICAN RUBBER TREE, AND THE BANANA. U. S. Dept. Agr., Bur. Plant Indus. Bul. 198, 64 pp., illus. 1911.

FACTORS THAT AFFECT DEVELOPMENT OF AXILLARY BUDS

The difference in the behavior of the axillary buds in the two types of cotton is of importance in relation to some of the production problems that are peculiar to certain of the irrigated valleys of the Southwest. In these regions the growing seasons are long, but the cotton plants are frequently forced to undergo periods of severe

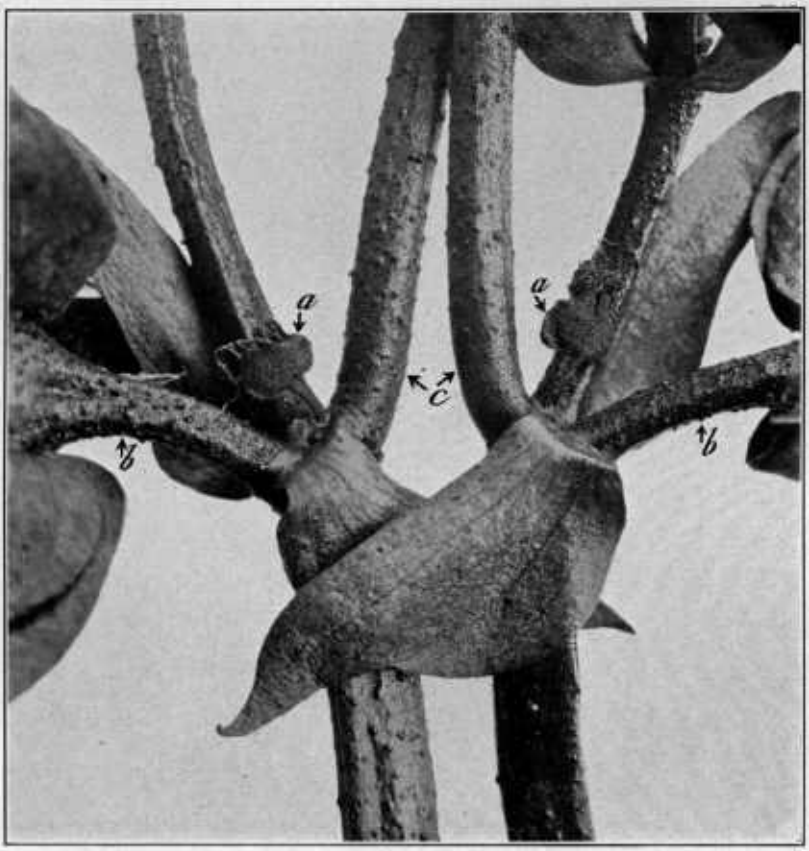

FIGURE 2.—Relative positions of extra-axillary and axillary fruit buds at each node on the fruiting branches of Pima Egyptian cotton plants. The small axillary buds or squares can be seen, at the base of the leaf petioles, as they appear when three or four days old, and are about ready to drop off or shrivel up. It will be noted that these buds usually do not develop the subtending leaf and stipules which characterize this type of bud in upland cotton: *a*, Axillary bud; *b*, pedicel of extra-axillary bud; *c*, petiole of leaf

stress, resulting from improper water relations when high temperatures prevail. Since the axillary buds on the fruiting branches of Egyptian cotton do not remain dormant and ordinarily survive for only a few days, it is apparent that any stimulus that would influence the retention and further development of these buds must be exerted before or during the few days when they are in full vigor of growth.

With upland cotton, on the other hand, the establishment of the proper conditions can apparently stimulate the growth of the dormant axillary buds at any time during the growing season, especially if the plants have previously thrown off a large part of their extra-axillary

fruit. In some of the hot interior valleys of the irrigated region the upland varieties are prone to undergo excessive shedding of buds and young bolls during periods of high temperature, and in some seasons many of the plants may shed all of the bolls and buds that are in the early stages of development during such periods. It has been observed that after climatic conditions have moderated near the close of an especially hot and unfavorable summer many of the upland plants that have undergone excessive shedding may begin to develop at almost every node, these short axillary branches bearing one or more floral buds. (Fig. 5.) Some even emerge from the first nodes near the main axis, where in rare cases a mature boll may be found on the same node.

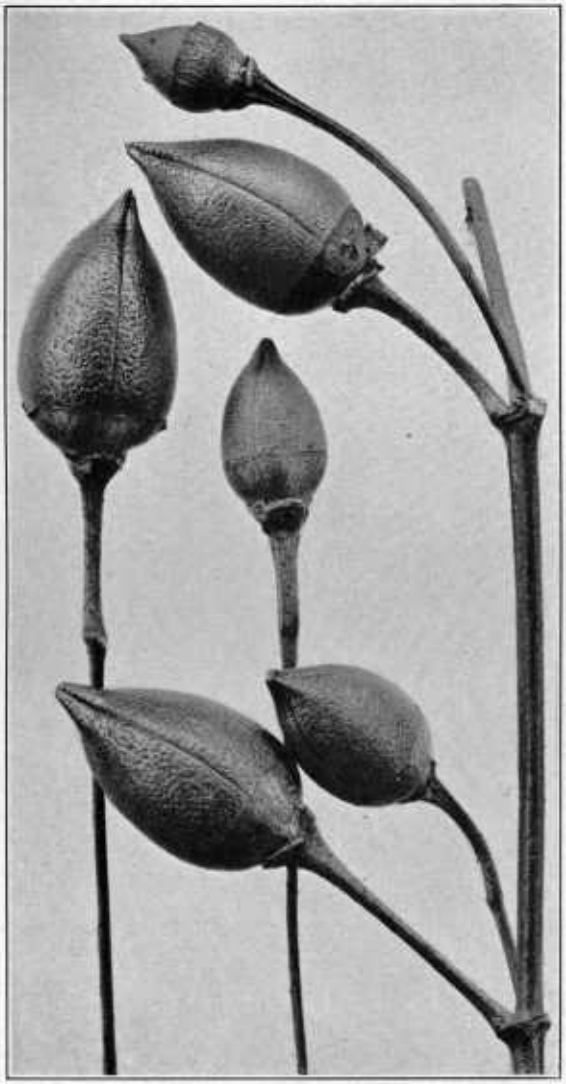

FIGURE 3.—Axillary and extra-axillary bolls of Pima cotton, showing difference in type of boll stems. The axillary bolls usually have long stems and often show some semblance of a joint

Not infrequently it may be observed that two cycles of flowering are in progress on the same fruiting branches, some of the later nodes bearing extra-axillary flowers while the older inner nodes may carry flowers on short axillary branches. (Fig. 6.) While under Arizona conditions a large number of these tardy floral buds may reach the flowering stage, it is only seldom that they reach maturity, on account of injury by frosts, and consequently they fail to play any important part in the final yield. However, where the seasons are longer, as in the valleys of southern California, it has been observed that in some seasons late-matured bolls from short axillary branches contribute materially to the yield.

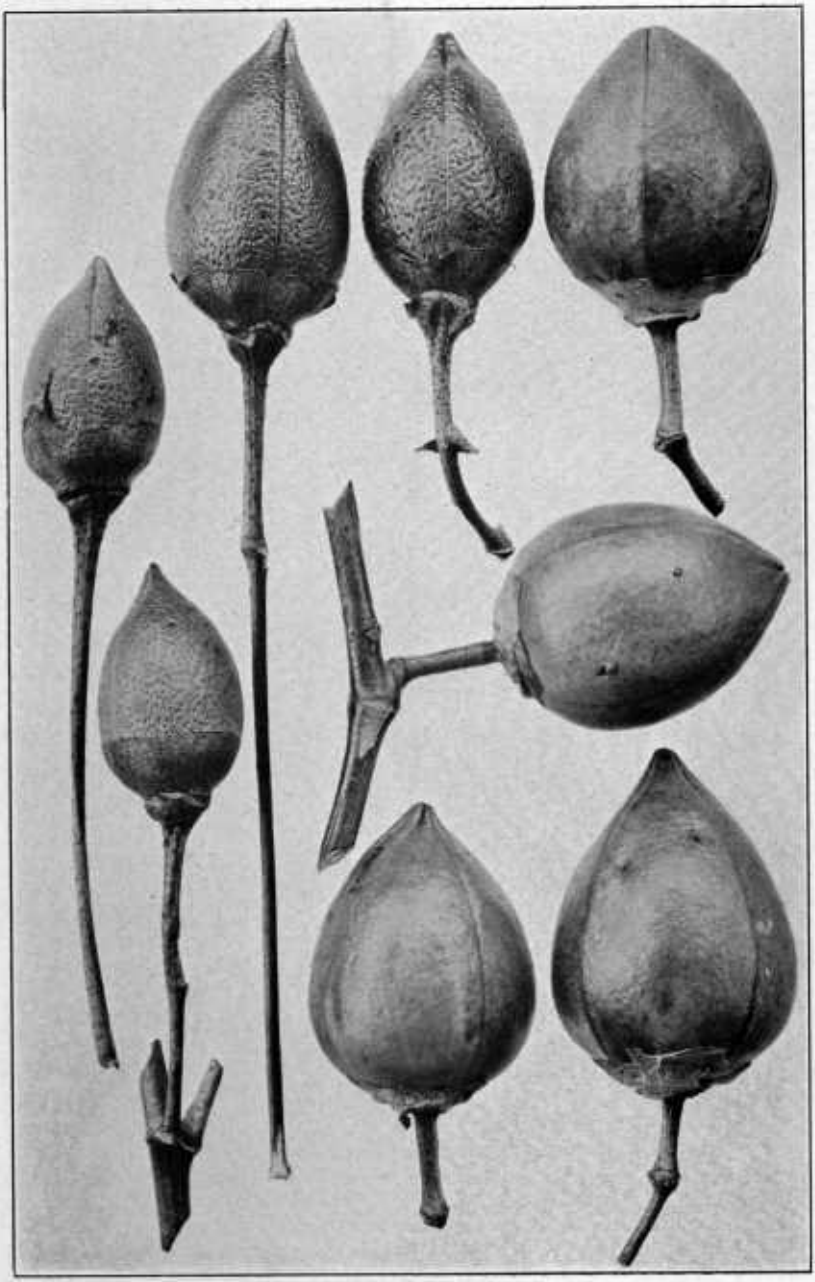

FIGURE 4.—Axillery bolls of Pima end Acala cotton, illustrating different types of pedicels. The four Pime bolls shown at the left and top center are smaller and heve longer stems end are more deeply pitted then the four Acale bolls

EFFECT OF REMOVAL OF EXTRA-AXILLARY BUDS ON DEVELOPMENT OF AXILLARY FRUIT

Experiments were begun in 1926 to determine to what extent the retention and development of axillary buds could be influenced by the removal of the fruit buds in the extra-axillary positions. In this season the defruiting process was not started until June 17, after the plants had already developed several fruiting branches, some of which had borne buds that had almost reached the flowering stage.

FIGURE 5.—A fruiting branch of Acala cotton (in two sections), showing an axillary boll developing at each node late in the season. The extra-axillary fruit had shed naturally from the first four nodes, and the scars are clearly shown. The flower at the fifth node is from an extra-axillary bud

Twenty-seven normal Pima plants were selected from a group of well-grown plants in a single row about 200 feet long, and all the fruit buds were removed from 17 of them on that date. Ten other plants of about equal size, interspersed among these 17, were selected as controls and tagged for observation as to the development of axillary fruit under normal conditions. In an adjacent row planted to the Acala variety 10 plants were selected on the same day and 5 of them were defruited, the other 5 being designated as controls. From June 17 until September 1 the extra-axillary fruit buds on the 17 defruited Pima plants and the 5 defruited Acala plants were pinched out every two or three days and a tag was attached to the internode to show the date of removal. On October 11, diagrams were made of all of the plants to show the location of the axillary fruit and the number

of vacant nodes. The data obtained from these diagrams are shown in Tables 1 and 2.

In 1928 a more careful study of axillary fruit production was conducted on 10 Pima and 9 Acala plants from which the extra-axillary

FIGURE 6.—Fruiting branches of Acala cotton, showing axillary buds ready to flower, on nodes behind flowers and bolls that have been developed in the extra-axillary positions. Thus it sometimes happens on upland cotton that a second wave of flowering may be in progress after that which normally occurs

buds were removed daily and on 10 control plants of each variety which were allowed to grow normally. The defruiting process was started on June 1 and discontinued on September 4. The influence of this defruiting on the plants is shown by the data in Tables 3 and 4.

TABLE 1.—*Growth of main stem, number of nodes and axillary buds developed, axillary buds shed and percentage retained on Pima and Acala cotton plants on which the extra-axillary buds were removed every two or three days during the season, at the United States Field Station, Sacaton, Ariz., in 1926*

Variety and plant No.	Height of plant	Nodes on fruiting branches	Axillary buds recorded on fruiting branches June 17 to Sept. 1	Axillary buds recorded as shed before flowering	Axillary buds retained to Oct. 11	Axillary bolls matured on main stem	Extra-axillary buds removed during season
Pima:	*Inches*	*Number*	*Number*	*Number*	*Per cent*	*Number*	*Number*
1	72	169	64	16	75.0	12	116
2	70	120	51	25	51.0	9	99
3	73	118	44	25	43.2	4	95
4	68	84	31	12	61.3	4	71
5	73	138	52	21	59.6	4	131
6	78	146	55	27	50.8	10	118
7	69	102	43	22	48.8	5	91
8	66	68	28	10	64.3	7	58
9	73	99	39	15	61.5	5	88
10	80	126	44	8	81.8	6	101
11	72	94	33	17	48.5	2	74
12	81	264	83	20	61.2	17	176
13	84	197	124	55	55.7	15	147
14	74	187	106	46	56.6	15	138
15	79	133	77	40	48.1	11	109
16	78	190	85	43	49.4	10	152
17	80	163	87	38	56.3	10	132
Mean	74.7±0.85	141.1±8.25	61.5±4.60	25.9±2.43	57.24±1.68	8.6±0.74	111.52±5.26
Acala:							
1	75	265	146	66	54.8	5	185
2	65	267	163	78	52.2	23	197
3	61	265	141	84	40.4	8	171
4	69	216	108	66	38.9	3	166
5	68	225	127	84	33.9	4	170
Mean	67.6±1.65	247.6±8.01	137.0±6.64	75.6±2.92	44.04±2.89	8.6±2.65	177.8±4.14

TABLE 2.—*Growth of main stem and number of nodes and axillary and extra-axillary bolls produced on normally developed Pima and Acala cotton plants at the United States Field Station, Sacaton, Ariz., in 1926* [a]

Variety and plant No.	Height of plant	Nodes on fruiting branches	Axillary bolls matured on fruiting branches	Axillary bolls matured on main stem	Extra-axillary bolls matured
Pima:	*Inches*	*Number*	*Number*	*Number*	*Number*
1	66	79	0	0	47
2	64	108	4	0	73
3	65	118	1	0	85
4	60	49	0	1	40
5	66	64	0	0	44
6	61	70	0	0	52
7	51	50	0	0	33
8	65	65	1	0	39
9	58	43	0	0	27
10	58	56	1	1	38
Mean	61.4±1.03	70.2±5.50	0.7±0.213	0.2±0.09	47.8±3.96
Acala:					
1	56	102	0	0	21
2	59	120	0	0	35
3	65	114	0	0	25
4	59	99	0	0	28
5	64	130	0	0	36
Mean	60.6±1.21	113.0±4.11	0	0	29.0±2.07

[a] The total number of axillary buds which developed and shed on the normally developed plants was not recorded in 1926.

TABLE 3.—*Number of nodes, axillary buds developed, axillary buds shed, and percentage retained on Pima and Acala cotton plants on which the extra-axillary buds were removed daily during the season, at the United States Field Station, Sacaton, Ariz., in 1928* [a]

Variety and plant No.	Nodes on fruiting branches	Axillary buds recorded on fruiting branches June 1 to Sept. 4	Axillary buds recorded as shed before flowering	Axillary buds retained to flowering	Extra-axillary buds removed during season
Pima:	*Number*	*Number*	*Number*	*Per cent*	*Number*
1	214	150	120	20.0	175
2	184	125	99	20.8	160
3	173	127	106	16.5	158
4	176	120	93	22.5	155
5	162	107	96	10.3	144
6	155	90	81	10.0	136
7	176	118	81	31.4	158
8	150	87	74	14.9	133
9	189	117	93	20.5	172
10	199	136	115	15.4	169
Mean	177.8±4.32	117.7±4.23	95.8±3.27	18.23±1.39	156.0±2.93
Acala:					
1	143	90	63	30.0	114
2	130	54	31	42.6	113
3	255	161	97	39.8	205
4	116	54	39	27.8	92
5	99	47	31	34.0	74
6	137	51	34	33.3	92
7	173	64	28	56.3	115
8	119	33	4	87.9	78
9	127	39	17	56.4	87
Mean	144.3±10.73	65.9±9.09	38.2±6.20	45.34±4.22	107.8±9.18

[a] The height of plants and the number of axillary bolls matured on main stem were not recorded in 1928.

TABLE 4.—*Number of nodes, axillary buds developed, axillary buds shed, percentage retained to flowering, and number of extra-axillary buds retained, on normally developed Pima and Acala cotton plants at the United States Field Station, Sacaton, Ariz., in 1928* [a]

Variety and plant No.	Nodes on fruiting branches	Axillary buds recorded on fruiting branches June 1 to Sept. 4	Axillary buds recorded as shed before flowering	Axillary buds retained to flowering	Extra-axillary buds retained to flowering
Pima:	*Number*	*Number*	*Number*	*Per cent*	*Number*
1	79	47	44	6.4	20
2	80	53	51	3.8	36
3	68	42	42	0	29
4	78	40	40	0	24
5	69	38	37	2.6	28
6	71	37	36	2.7	24
7	64	34	32	5.9	24
8	53	30	29	3.3	20
9	51	25	25	0	25
10	63	36	35	2.8	25
Mean	67.6±2.23	38.2±1.76	37.1±1.66	2.75±.503	25.5±1.02
Acala:					
1	98	2	2	0	50
2	78	5	5	0	38
3	93	0	0	0	29
4	109	22	22	0	31
5	90	4	4	0	36
6	81	1	1	0	34
7	87	5	4	20.0	37
8	104	2	2	0	54
9	98	1	1	0	47
10	96	6	6	0	41
Mean	93.4±2.13	4.8±1.40	4.7±1.39	2.0±1.39	39.7±1.81

[a] The height of plants and the number of axillary bolls shed after flowering were not recorded in 1928.

It will be observed from these data that the removal of the fruit buds in the extra-axillary positions caused the plants to grow taller than normally and to produce a much greater number of internodes. The fruiting branches of the defruited plants were much longer than those of the normal plants and a greater number of fruiting branches was developed. In 1926 the mean number of internodes produced on the defruited Pima plants was 141 ± 8.3, while the mean number on the normal Pima plants was 70 ± 5.5. Since the observations were not continued throughout the season, the number of axillary buds recorded in the tables does not represent the total number that developed, as many buds had appeared and shed before the observations were begun, and a larger number appeared after September 1. In 1926 an average of 111 ± 5.3 extra-axillary buds were removed from the Pima plants and 178 ± 4.1 from the Acala plants, and in 1928 an average of 156 ± 2.9 buds per plant were removed from the Pima plants and 108 ± 9.2 from the Acala plants. A large proportion of axillary buds were developed to maturity on some of the defruited plants; in some cases three or four bolls were matured on a single branch. (Fig. 7.) In 1926 the mean percentage retained until the end of the season was 57.2 ± 1.7 for Pima and 44.0 ± 2.9 for Acala. The effects of the defruiting on the retention of the axillary buds did not become apparent on the Pima until the process had been in progress for some time. Very few axillary bolls were developed on the

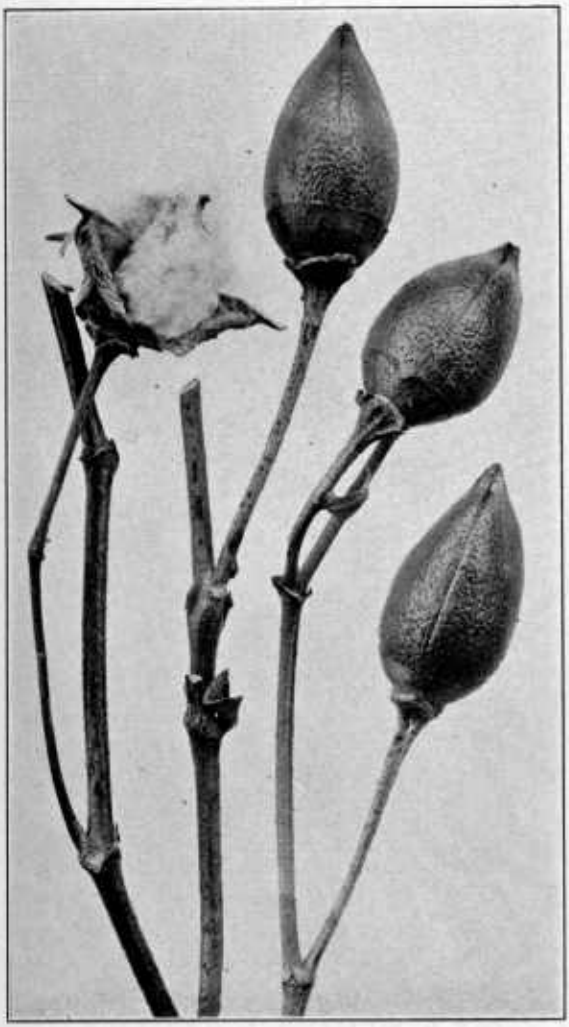

FIGURE 7.—Axillary bolls produced on a single fruiting branch of a Pima cotton plant on which no extra-axillary fruit was allowed to develop

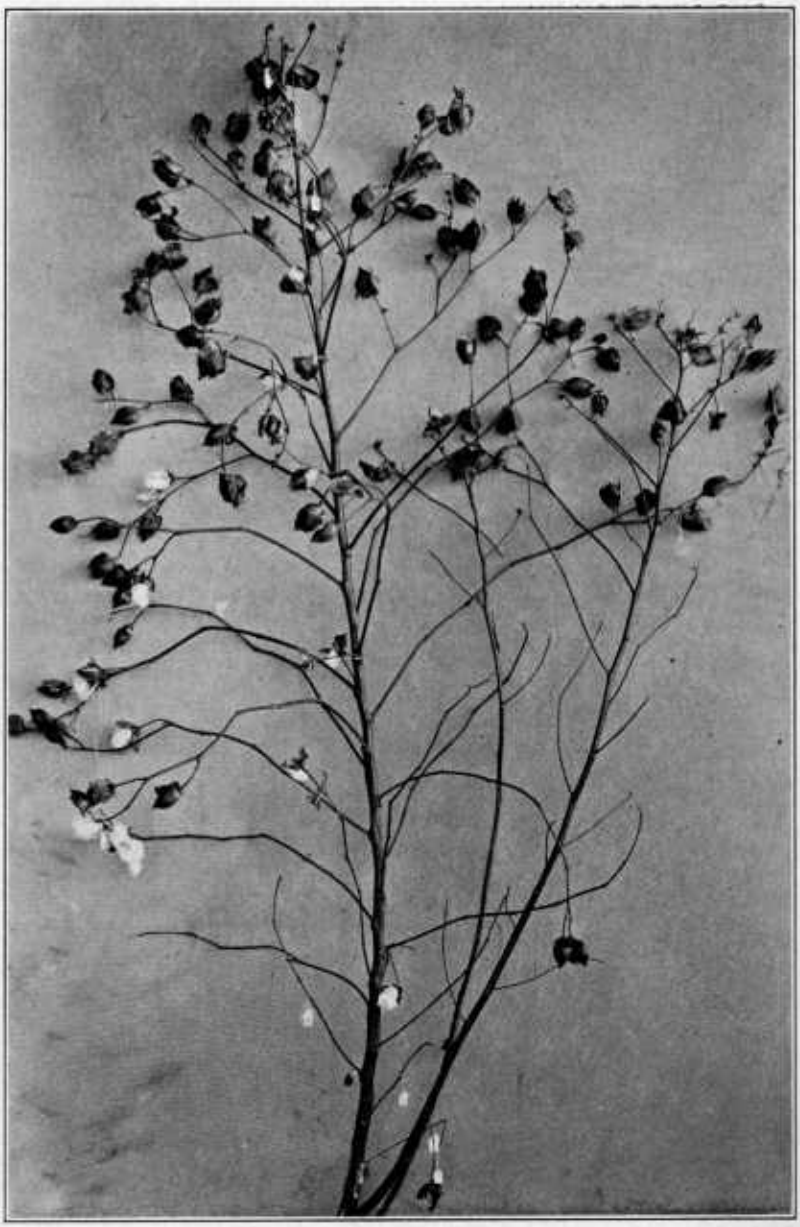

FIGURE 8.—Pima cotton plant showing bolls produced from axillary buds. The extra-axillary buds were removed every two or three days during the season

lower branches of the Pima plants, and at the end of the season most of the axillary bolls retained were found on the outer nodes of the middle branches and on the late-developed branches at the top.

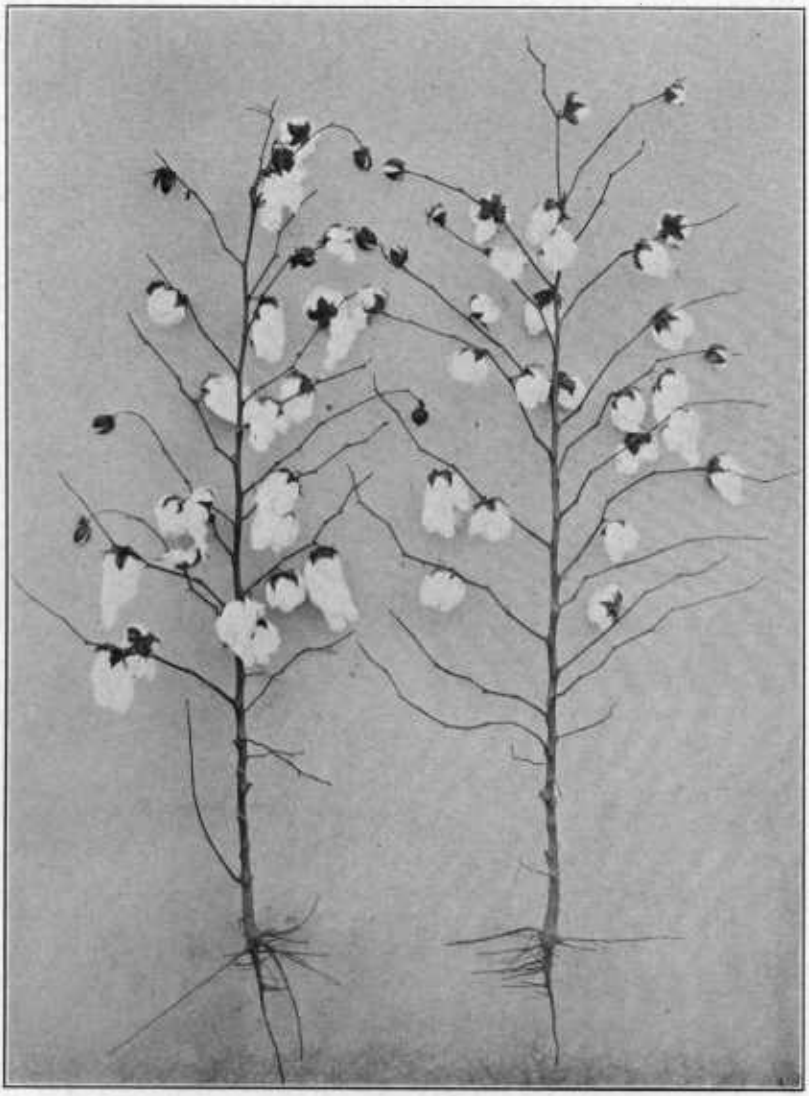

FIGURE 9.—Two Acala cotton plants that have produced bolls from axillary buds only. The extra-axillary buds were removed daily soon after they appeared. Note that many of these bolls are developed on nodes close to the main axis, while most of those on Pima cotton (fig. 8) developed on outer nodes and near the top of the plant. This is due to the fact that axillary buds on upland cotton usually remain dormant and may be stimulated to growth at any time, while on Pima cotton the axillary buds are shed or dry up on the plants a few days after appearance unless some stimulus occurs to force them into further development

(Fig. 8.) With the Acala variety, however, many of the axillary buds on the inner nodes of the lower branches became active after defruiting had been carried on for a time, and at the end of the season a considerable number of matured axillary bolls were found on the

lower and middle branches, even on the nodes near the main axis. (Fig. 9.)

It will be observed that very few axillary buds developed to maturity on the normal plants of Pima or Acala in either 1926 or 1928. However, plants grown under the most favorable conditions often develop to maturity a considerable number of axillary bolls in addition to the extra-axillary crop. In 1927 a count showed that the mean number of axillary bolls matured on five large, wide-spaced Pima plants was 6.4, in addition to a mean of 68.2 extra-axillary bolls.

In Arizona certain varieties show a greater tendency than others to produce axillary fruit. Plants of the sea-island type, which in this region usually do not produce any bolls until late in the season, often produce large numbers of axillary bolls on the upper fruiting branches and on the outer nodes of older branches. In 1927, 10 representative sea-island plants set an average of 9.3 axillary bolls per plant. The native southwestern varieties, Hopi and Sacaton Aboriginal, also show a tendency to produce an unusual amount of axillary fruit. Diagrams made of 10 Sacaton Aboriginal plants in 1927 showed an average of 10.2 axillary bolls per plant.

AXILLARY BUD DEVELOPMENT ON PLANTS AFFECTED WITH CRAZY-TOP DISORDER

In recent years there has appeared in many cotton fields of the Salt River Valley a peculiar disorder known as crazy top, which causes sterility and results in many abnormalities of the affected plants. In studying the effects of this disorder on the plants it has been observed that upon the arrival of cooler and more favorable weather conditions in the fall some of the more luxuriant upland plants that have been almost sterile from crazy top will begin to develp axillary branches and bear floral buds at many of the nodes from which extra-axillary bolls have been shed. Pima plants that have been rendered practically sterile by the disorder, although having no reserve axillary buds on the lower internodes of the branches as do the upland plants, are able to produce "supernumerary" bolls late in the season on new joints, by retaining a large proportion of the axillary buds. Frequently large clusters of bolls are observed in the tops of Pima plants affected with crazy top as a result of this tendency toward recovery. (Fig. 10.) As in the case of sterility from normal stress effects, the development of this fruit from axillary branches occurs late in the season, and it is not often that enough of it matures to be a factor in production. However, it is of interest from the standpoint of physiology and from its indication that there is a tendency toward recovery from the disease.

SHEDDING OF AXILLARY BUDS ON EGYPTIAN COTTON

It would appear that some investigators have failed to recognize that there is a difference in the morphology of the Egyptian and upland cotton plants with respect to the axillary buds. In studying the relative proportions of buds, flowers, and bolls from 1,300 Egyptian plants at Giza, in Egypt, Balls [5] collected weekly all the mate-

[5] BALLS, W. L. THE COTTON PLANT IN EGYPT. 202 p., illus. London. 1912.

rial beneath the plants and presented an analysis of the results in the form of shedding curves.

Bailey and Trought,[6] working with the Ashmouni, Assili, and Sakellaridis varieties, found "that the great majority of buds fall off at a very early stage when the bud is only about 2 mm. or less in width measured across the epicalyx." In an experiment carried out in 1923 they reported that the number of buds and bolls which were shed by 40 Sakellaridis plants during the period June 26 to September 26 was as follows:

Small buds (not more than 5 mm. in diameter)	787
Larger buds	275
Bolls (all ages)	92

From these data they concluded that "about 60 per cent of the 'possible crop' was lost in this case through bud shedding, while

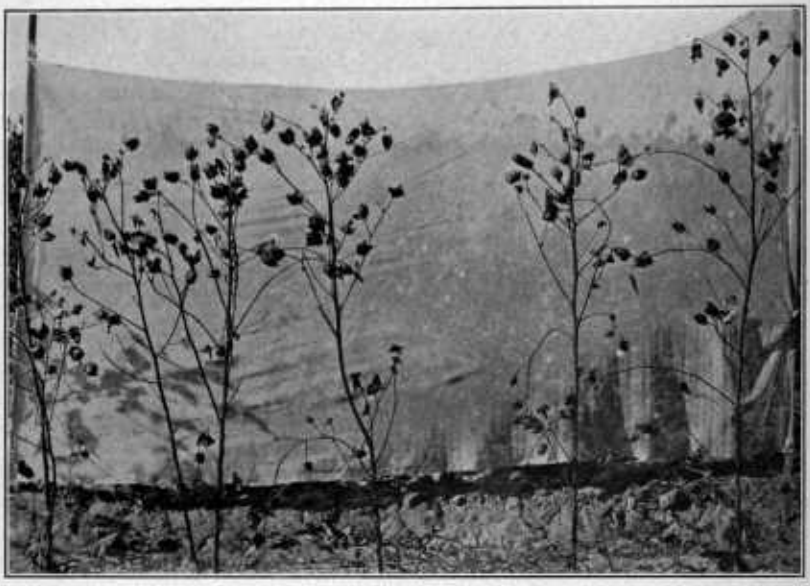

FIGURE 10.—Pima cotton plants as they commonly appear late in the season when affected by the crazy-top disorder. It will be noted that most of the bolls that are set are on the terminal nodes. A part of the crazy-clustered appearance of the bolls is due to the retention of the axillary fruits

boll shedding accounted for about 6 per cent of the total." In this experiment, as in those conducted in 1921 and 1922, these investigators used the "catch-net" system of collecting all of the buds that dropped off each day and classified them into ages according to size.

The experiments conducted by the writer indicate that in a study of bud shedding the method of collecting the fallen buds from the ground or in catch nets is open to serious error. Should this method be followed with Pima Egyptian cotton, the number of squares falling into the class measuring less than 5 mm. across the epicalyx would be far too high if considered as an actual loss of "possible crop," since it is never possible to obtain two bolls at each node throughout the plant, no matter how favorable the conditions.

[6] BAILEY, M. A., and TROUGHT, T. GROWTH, BUD-SHEDDING, AND FLOWER PRODUCTION IN EGYPTIAN COTTON. Egypt Min. Agr., Tech. and Sci. Bul. 65, 8 pp., illus. 1927.

Obviously, many of the rudimentary axillary buds, which emerge with as great regularity as the "normal" buds, but which only rarely develop into bolls, would be included in the count, since under ordinary conditions they drop off when at a size of from 1 to 5 mm. across the epicalyx, though many shrivel up and remain attached to the plants for long periods.

The great similarity of these axillary buds and the extra-axillary buds would make it impracticable to distinguish between the two kinds if all were collected together. (Figs. 11 and 12.) It will be seen from Table 4 that the mean number of axillary squares developed on the normal Pima plants between June 1 and September 4, 1928, was 38 ± 1.8. Practically all of these were shed, and had they been counted with the shed extra-axillary squares the total number would have been nearly twice as great as the mean number of vacant extra-axillary nodes on the plants.

SUMMARY

The axillary buds and branches on the fertile branches of Egyptian cotton differ in morphology and behavior from those on upland cotton.

In the Pima variety of Egyptian cotton rudimentary axillary branches begin development with the advent of minute triangular buds in the axil of each leaf, but ordinarily this development is cut short by the shedding or drying up of the buds, which maintain active growth for only a few days.

In upland varieties the axillary buds usually remain dormant, but they can be stimulated to growth at any time later in the season.

In Arizona, axillary buds on upland plants frequently begin development late in the season, especially on luxuriant plants that have shed excessively during the summer, and a second cycle of flowering may occur on the older fruiting branches.

The axillary buds and bolls on both types of cotton are usually developed too late to contribute materially to the yield under Arizona conditions.

Removal of the extra-axillary buds artificially by pinching off the new buds at frequent intervals resulted in more axillary buds being retained by the Pima plants and many of them continued development to maturity.

The removal of the extra-axillary buds on upland plants stimulated many of the axillary buds into development, and a considerable number of them were retained by the plants until maturity.

On the defruited Pima plants the axillary fruits that matured were located only on the internodes developed late in the season, while on the defruited upland plants a greater part of them matured on the internodes developed earlier in the season.

The artificial removal of the extra-axillary buds caused the plants to grow much taller and to produce longer and more numerous fruiting branches than normally.

Both Pima and upland plants that have been rendered almost sterile during the summer from effects of the crazy-top disorder may develop a large number of axillary fruits late in the season, those on

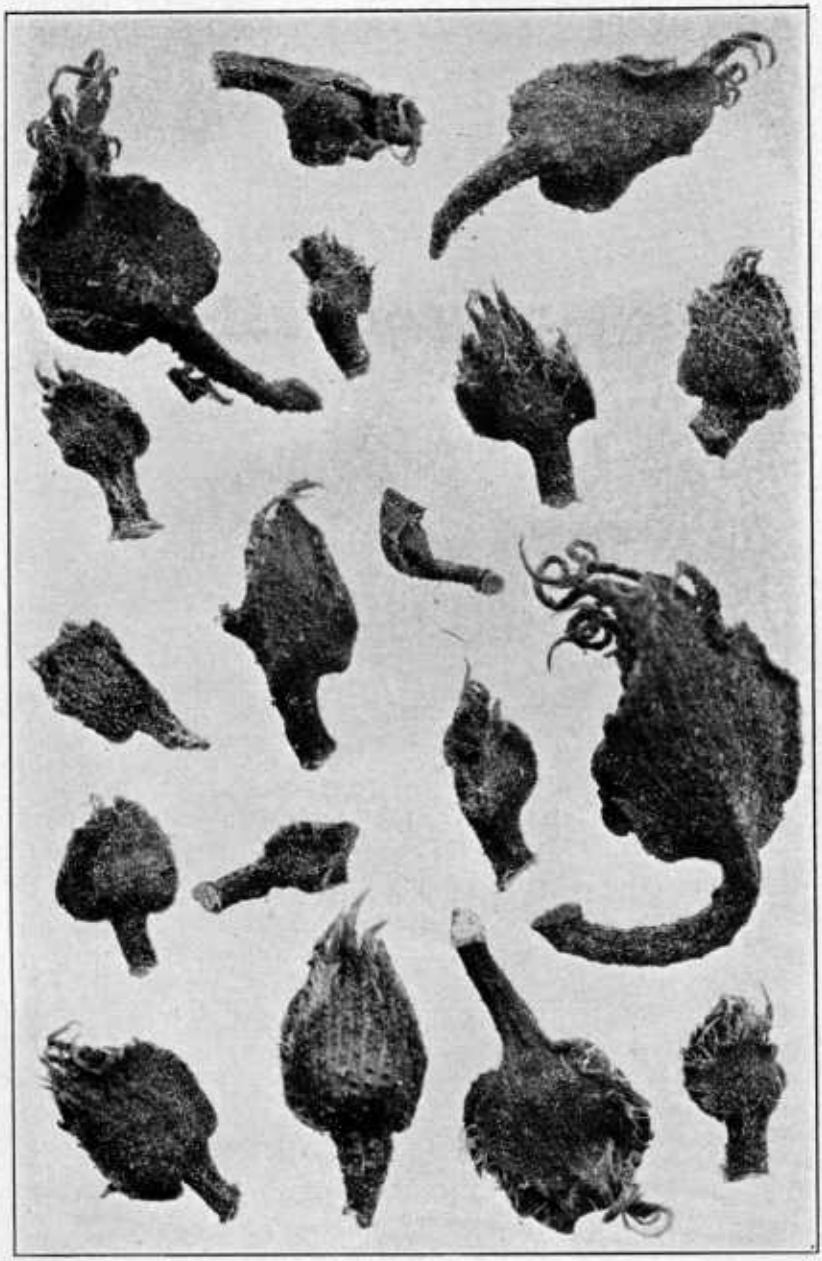

FIGURE 11.—Axillary buds from Pima cotton plants, collected when ready to become separated from the plants by abscission. Note that some are almost identical in shape with the extra-axillary squares shown in Figure 12. × 10

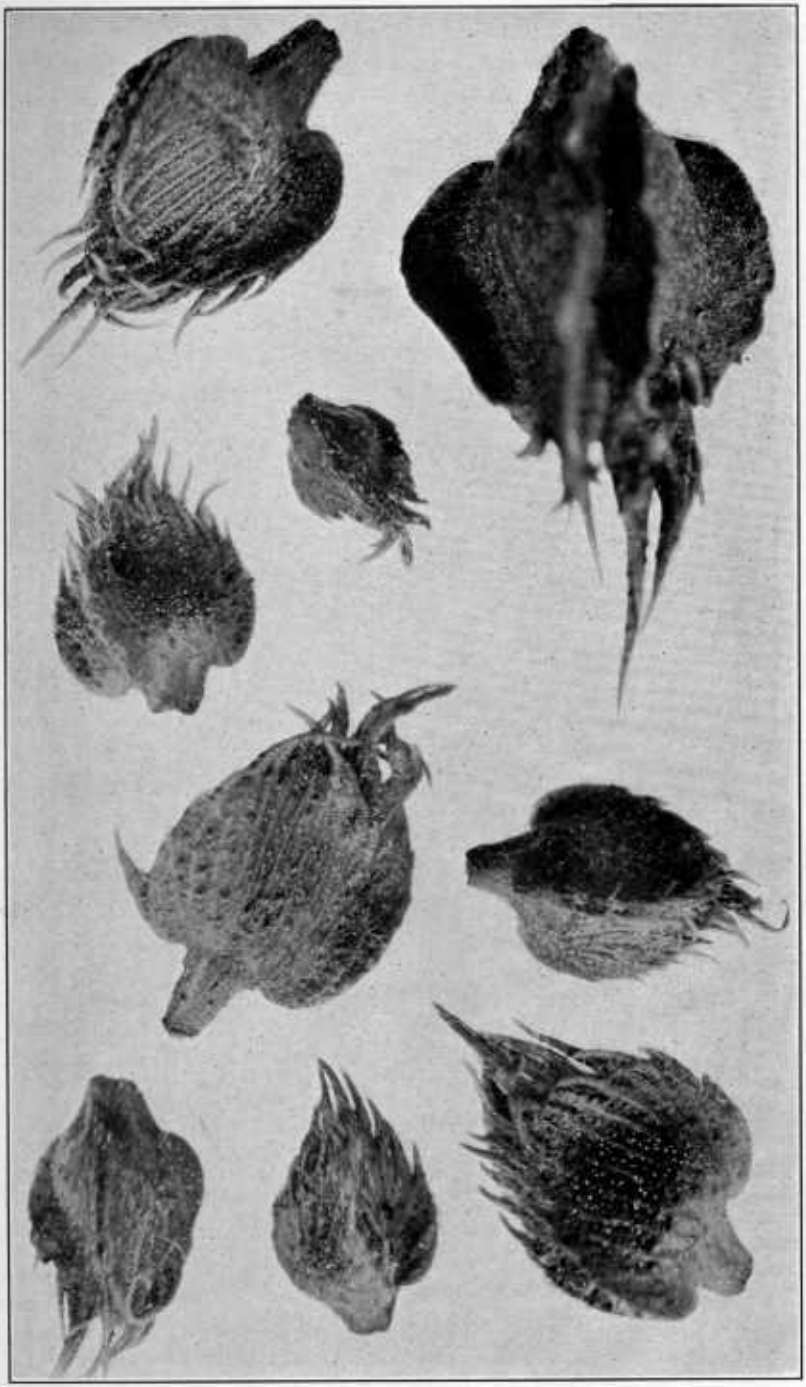

FIGURE 12.—Extra-axillary squares from Pima cotton plants, collected when only a few days old. × 10

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the upland plants being produced on both early and late developed internodes, while those of Pima form only on the late growth.

The large numbers of very small buds that are shed naturally from the axillary positions on Egyptian cotton make it impracticable to use the method of collecting the shed squares or young bolls as a basis for estimating the "possible crop" or for assigning a proper ratio of shed buds and bolls, as has been attempted by some investigators.