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Earliness Factors in Three Pima Cotton Genotypes[1]

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ABSTRACT

Pima cotton cultivars (*Gossypium barbadense* L.) were characteristically tall and late maturing, but newly developed Pima genotypes are shorter and earlier. The objective of this study was to ascertain phenotypic differences between the early and late Pima genotypes and relate them to earliness characters in upland genotypes (*G. hirsutum* L.). Among three Pima genotypes, characters studied were plant height, stem and branch weight, number of mainstem nodes, mainstem internodal length, node of first sympodium, cut-out node, axillary bolls on mainstem, early bolls set and shed, and late green and mature bolls. Data from dried plants collected at end-of-season were obtained for 1980, 1981, and 1982 at Phoenix, AZ. Early season genotypes, when compared to late season genotypes, had i) shorter mainstem and sympodial internodal length, ii) less stem weight, iii) lower first sympodium node, iv) lower cut-out node, and v) more bolls on the mainstem that developed in the axils of the sympodia. On the first 30 fruiting sites per plant that flowered, the early genotypes set more bolls and shed fewer bolls on a smaller number of sympodia. The early genotypes showed a larger fruiting-efficiency ratio of mature fruit numbers to stem weight, and a larger proportion of all the fruits per plant in the group of first 30 fruiting sites. Many of the earliness characters were similar to those in upland cotton. Fruiting-efficiency ratio may be the most useful selection parameter.

Additional index words: ***Gossypium barbadense*** **L., *G. hirsutum* L., Phenotypic characters, Plant height, Plant weight, First sympodial node, Cut-out, Axillary fruit.**

EARLINESS in upland cotton (*Gossypium hirsutum* L.) has often been reported as a time-quantity measure based on sequential pickings (1,7,16,18,19). Phenotypic characters also have been associated with earliness. The mainstem node number of first sympodium (fruiting branch) was considered to be the most reliable phenotypic indicator of earliness (6,10,13,15,16,17,19). Other characters in upland cotton related to earliness are smaller plant types (14,15,16,21), increased boll set and decreased boll shed on early sympodia (14), and fewer and shorter mainstem internodes (16).

Historically, Pima cotton cultivars (*G. barbadense* L.) were described as tall, late maturing, and often flowering until the end of the season. In 1980, two short-statured and earlier-maturing breeding lines of American Pima cotton were released for use in interspecific hybridization with upland cultivars (3). These breeding lines represent new and previously unavailable germplasm in *G. barbadense*.

The objective of this study was to ascertain phenotypic characteristics that relate to earliness in the newly developed genotypes in American Pima cotton, and to relate them to phenotypic characters affecting earliness in upland cotton.

MATERIALS AND METHODS

Two early maturing experimental Pima genotypes, 79-106 and 79-103 (3), and a late maturing cultivar, Pima S-5, were grown for 3 years at Phoenix, AZ. The genotypes 79-106 and 79-103 are approximately 2 weeks earlier in maturity than Pima S-5, and are of comparable fiber quality. A high degree of heat tolerance and fiber quality was maintained in the development of these new genotypes even at lower and warmer elevations (4). Plantings were 16 Apr. 1980, 27 Mar. 1981, and 1 Apr. 1982, in a randomized complete block design with four replications. Plots were four rows 99 cm apart and 11 m in length with data collected from one of the two center rows. Soil was an Avondale clay loam (a member of the fine-loamy mixed, hyperthermic family of Typic Torrifluvents). Conventional management practices including insect control were used each year.

The growth and fruiting characters were measured on five dried plants per plot at the end of the season. Characters measured were plant height, stem and sympodia dry weight, mainstem internodal lengths, total sympodial lengths, and the fruiting status of each fruiting site including secondary sites on the mainstem for early and late bolls. Early fruits were selected from the first 30 fruiting sites that flowered on each plant (13). Late fruits were all others including those on the fifth and higher sympodial nodes.

On the dried plant material a mature fruit was identified by the remaining burr, a shed boll by a large oval scar at a fruiting node, and a shed square by a smaller scar as distinguished from a triangular scar of a leaf. Small dried squares, immature bolls, rotten bolls, and shed branch tips (11) were identified but not included in the analyses.

The variance among the yearly means from the split-plot analysis of variance of the means for the 3 years (main variable) and genotype (secondary variable) was generally insignificant and is not shown in the tables.

RESULTS AND DISCUSSION

Earliness is the Pima genotypes, 79-106 and 79-103, compared to Pima S-5, was established by five sequential hand pickings (4). The percentage of total yield for each picking is shown in Fig. 1. The earliest genotype, 79-103, was 22% more productive than Pima S-5 by the third picking. The 79-106 genotype was intermediate in all the pickings. Calculated mean-maturity dates (MMD) were 181, 172, and 168 days after planting for Pima S-5, 79-106, and 79-103, respectively (1,16,17,18,19). A production rate index (PRI) was calculated by dividing the final seed-cotton yield by MMD (1). The 79-106 genotype produced seed-cotton at the highest rate, 8.17 kg ha^{-1} day^{-1}, while 79-103 and Pima S-5 produced 7.19 and 7.16 kg ha^{-1} day^{-1}.

The vegetative and fruiting characters presented in Tables 1 to 3 were measured at the end of the season from defoliated and dried plants. In the two early genotypes, 79-106 and 79-103, plant height and stem weight were significantly lower than the cultivar Pima S-5. The genotypes 79-106 and 79-103 averaged 78% and 63% the height of Pima S-5, respectively. In stem weight the respective percentages were 63 and 55 showing a greater percentage reduction in stem weight than in plant height in the early geno-

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types. In upland cotton the early maturing, modern strains also have been reported to be smaller in stature (14,15,16,21) and of less dry weight (20). Wells and Meredith (21) suggested that modern upland cultivars do not partition as much dry matter into vegetative portions during reproductive growth as did older cultivars. A similar relationship exists in the new Pima genotypes.

The number of mainstem nodes did not show a large percentage decrease in the early genotypes although a low CV of 1.9% for genotypes explains the significance between means. The average mainstem internodes decreased in length in the shorter genotypes. Total sympodial lengths in each plant were determined by placing all the branches end to end. Shorter sympodia appeared on the smaller genotypes. In the early genotypes both the decrease in length of mainstem internodes and the decrease in node number explains the large decrease in plant height. In upland cotton Quisenberry (16) has reported that dwarf stocks have fewer nodes and shorter internodes of mainstems and sympodia compared to normal height plants.

The mainstem node of the first sympodium or first flower has been reported to be a valid indicator of earliness in upland cotton with a trend to lower nodes in the early cultivars (6,10,13,15,16,17,19). In the present study the lowest sympodium that supported at least one mature boll was labeled the first sympodium, and although there was a trend to lower nodes in the early genotypes, the mean node level of the first sympodium was not significantly different among the genotypes (Table 1).

Mainstem internodes which vary in length along the stem may be shortened in response to water stress

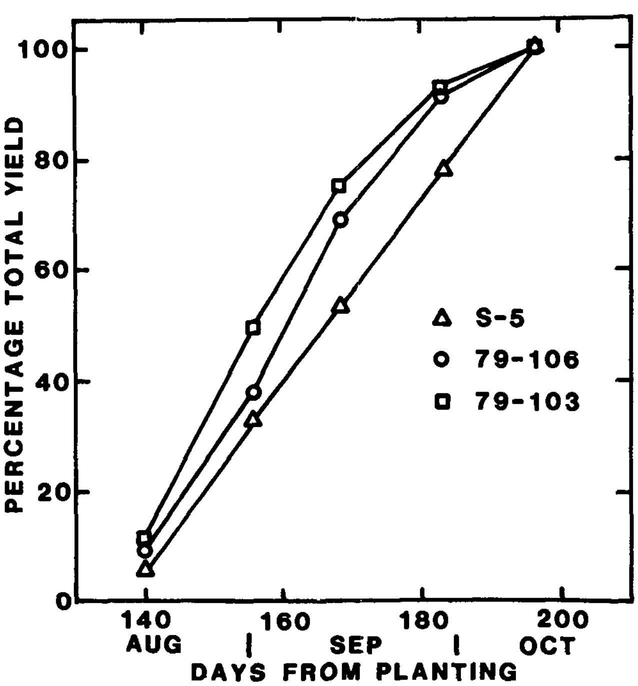

Fig. 1. Fraction of total seed cotton yield in three Pima genotypes on five harvest dates throughout the growing season. Data points are seasonally adjusted mean values for 1980, 1981, and 1982.

Table 1. Vegetative and fruiting characteristics of tall and short Pima genotypes.

	Genotype		
Variable	S-5	79-106	79-103
Plant height (cm)	118.0a*	92.3b	74.7c
Stem and branch dry wt (g/plant)	54.6a	34.4b	30.3c
No. of mainstem nodes	31.1a	30.2b	29.0c
Mainstem internodal length (cm)	3.7a	3.0b	2.6c
Total sympodial length (cm)	517.1a	401.0b	351.5c
Mainstem node of first sympodium	8.2a	7.8a	7.3a
Cut-out node	27.1a	25.2b	23.3c
Axillary bolls on mainstem	1.1b	1.8b	3.1a

* A split-plot ANOVA was applied to the years as main treatments and genotypes as sub-treatments. Differences of yearly means were generally not significant and are not shown. Means in the same rows followed by the same letter are not significantly different at the 0.05 probability level by Duncan's Multiple Range Test.

or lack of assimilate. Water-stress periods that occurred before furrow irrigations generally decreased stem elongation for a few days. A pattern of long and short internodes was observed and was found related to irrigation schedules (not shown). However, in the present study shortened mainstem internodes that appeared mid- to late-season seemed to be unrelated to the irrigation schedule and were probably caused by an assimilate stress commonly called cut-out (15). Mainstem nodes at which cut-out occurred were identified easily in the short genotype 79-103. The internodal length of 79-103 decreased to less than 1 cm in 93% of the plants and in 79-106 the internodal lengths decreased to about 1.2 cm in 70% of the plants. In Pima S-5 the shortest internodes were 1.6 cm and were found in 26% of the plants, the remainder of the plants showing little or no evidence of cut-out. Data in Table 1 shows that cut-out nodes were lower on the mainstem in the short plants. The cut-out at a lower node relates to the shorter genotype accumulating boll loads earlier in the season than did the taller genotype.

A characteristic of Pima genotypes is axillary fruiting on the mainstem and on sympodia (8). Axillary fruits that appeared on the mainstem were added to the total fruiting potential of a genotype. The early maturing 79-103 had 12% more mainstem bolls than did Pima S-5, and the 79-106 genotype was intermediate. Axillary fruiting was not a selection criterion during the development of the two early Pima genotypes but may be considered in future germplasm development.

The first 30 fruiting sites that flowered on each plant were selected to represent the early fruits (13). The three Pima genotypes produced 98% of all fruit on the first four sympodial nodes with plant densities about 90 000 plants ha^{-1}. An exception was the first and second sympodia above the cotyledonary node where only two and three potential flower sites, respectively, were observed.

Early fruiting characteristics for the Pima genotypes were shown in Table 2. The number of sympodia bearing the first 30 flowers was found to occur in a narrow range, 12.9 to 13.4, among the three genotypes. The nodes of the highest sympodia bearing the early fruits also were found to occur in a narrow range, 19.2 to 20.6. In upland cotton Quisenberry (15,16) found small differences in numbers

Table 2. Early fruiting characteristics of the first 30 fruiting sites that flowered in tall and short Pima genotypes.

	Genotype		
Variable	S-5	79-106	79-103
No. of sympodia	13.4a*	13.3a	12.9a
Highest sympodium	20.6a	20.2ab	19.2b
Early bolls retained per plant	19.4b	21.4b	24.7a
—1st node	8.5a	9.6a	10.5a
—2nd node	6.2a	6.5a	7.7a
—3rd node	3.6a	4.0a	4.8a
—4th node	1.1a	1.4a	1.7a
Early bolls shed per plant	11.5a	8.5b	5.4c
—1st node	4.1a	3.0ab	2.1b
—2nd node	3.5a	2.7a	1.5b
—3rd node	2.6a	1.9ab	1.1b
—4th node	1.3a	0.8b	0.6b
Percent of possible fruit sites that flowered	77	76	79

* See footnote for Table 1.

of mainstem nodes between normal and dwarf stocks.

The Pima 79-103 genotype set about 27% more early bolls than Pima S-5 and shed approximately 47% fewer bolls (Table 2). Boll set and shed was intermediate for the 79-106 genotype. The concept that more fruiting sites bearing fruit on lower nodes leads to earliness has been reported in upland cotton (6,13,14), and the data in Table 2 shows that the same concept holds true for early Pima genotypes. Also shown in Table 2 is the breakdown for the number of bolls that set and bolls that shed at the four sympodial nodes included in the first 30 flower sites. On each of the four nodes there was a tendency to set more bolls and shed fewer bolls in the early genotypes compared to Pima S-5. Retention of the early bolls was highest at the first node (5) and in the shortest genotype. Percentage retention of the early bolls for Pima S-5, 79-106, and 79-103 was respectively 68, 76, and 84 at the first sympodial node and 45, 63, and 72 at the fourth node. Retention for nodes 2 and 3 was intermediate. The greater retention in the early genotypes provided an increased assimilation sink and resulted in a greater partition of dry matter into reproductive growth (21). Shedding of bolls was highest at the first node of Pima S-5.

The mean percentage distribution of retained bolls on each node for the three genotypes was 44, 31, 19, and 6 for sympodial nodes 1 through 4, respectively. Although Pima S-5 was developed about 8 years prior to the early genotypes, there was little difference among the three in the percentage distribution of bolls. Thus in all three genotypes 94% of early yield came from the first three sympodial nodes. In contrast, an obsolete cultivar, Pima S-4, had 80% of the total yield produced by the first three nodes, where the percentage of bolls set on nodes 1-4 and higher were 35, 25, 20, 9, and 11, respectively (9). This suggests a more efficient use of sympodial nodes near the mainstem in current Pima genotypes. In comparison, the first two sympodial nodes of a current upland cultivar contribute 97% of the total yield (12).

The short genotypes retained more bolls than did Pima S-5 on the early fruiting sites and produced flowers on a greater percentage of possible fruit sites included in the first four sympodial nodes. Both square shed and branch terminal shed (11) lowered the percentage of possible fruit sites that flowered.

Table 3. Comparison of late-season and total fruiting characteristics in tall and short genotypes.

	Genotype		
Variable	S-5	79-106	79-103
Late mature bolls/plant	12.8a*	11.1a	10.1a
Late green bolls/plant	7.4ab	8.7a	6.6b
Total mature bolls/plant	33.2a	34.2a	37.9a
Percentage early bolls of total	58	63	65
Fruiting efficiency ratio†	0.6b	1.0a	1.3a

* See footnote for Table 1.
† Ratio of total number of mature bolls to stem and branch dry weight (g).

The late-season fruit included all bolls borne on the sympodial and mainstem nodes that were located above and beyond the limits of the early fruits. In Table 3 the earliest genotype, 79-103, had the fewest number of both green bolls and mature bolls. The total number of mature bolls per plant (early and late sympodial bolls and those on the mainstem) were not significantly different although there was a trend to set more bolls on the early genotypes similarly to modern upland cultivars (21). The first 30 flower sites represented a smaller percentage of the total in Pima S-5 than in the shorter and earlier 79-103 because of the lengthened flowering period in Pima S-5. This resulted in a more uniform rate of boll opening in Pima S-5 (Fig. 1) and more late green bolls than in the 79-103.

A fruiting efficiency ratio was calculated by dividing the dry weight of mainstem and sympodia by the number of bolls per plant and expressed as grams of dry matter per boll produced. Table 3 shows higher fruiting efficiency ratios in the early genotypes than in Pima S-5, related in part to the ranker vegetative growth of Pima S-5 and an increased shedding of bolls. The reproductive to vegetative ratios of modern upland cotton cultivars have shown similar tendencies toward a higher relative fruitfulness and a larger fraction of available photosynthate appeared to be utilized by the bolls than in the tall plants (2,6,14,20,21).

The data for Pima genotypes reported in the present paper support the general hypothesis of the cause of earliness in cotton. Wells and Meredith (20, 21) indicated in upland cotton that modern cultivars partitioned assimilates earlier into increased fruit numbers and dry weights when compared to obsolete cultivars. The increased retention of bolls in the short cotton plants may have resulted from a better light distribution in the canopy (5). Beyond a certain boll load, cotton plants of a smaller biomass appeared to be less able to supply assimilates to an increasing fruit load. Consequently, plant growth and fruiting in short genotypes slowed and cut-out sooner and the existing bolls matured earlier (6). The new, early Pima genotypes when compared to the older Pima S-5 genotype set and retained more fruit on lower nodes on smaller plants and on fewer fruiting sites. This doubled the fruiting efficiency ratio of 79-103, the earliest Pima genotype. Axillary bolls on the mainstem furnished additional early fruits.

A composite view of all of the characters discussed above appears meaningful from the standpoint of germplasm enhancement. The most useful parameter may be the fruiting-efficiency ratio because it involved both plant vegetative dimensions and yield. This selection criteria could be important in future Pima cotton germplasm development and enhancement.

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