

# CROP SCIENCE

Volume 21

September–October 1981

Number 5

## Early Vegetative Growth of Cotton as Influenced by Leaf Type<sup>1</sup>

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### ABSTRACT

Cotton (*Gossypium hirsutum* L.) plants with mutant Okra (L<sup>o</sup>) and Super Okra (L<sup>s</sup>) leaves have several desirable characteristics in production systems with narrow rows and with standard rows where humidity and boll rot are high. These leaf types cause a modified fruiting expression in cotton plants. This investigation was conducted to determine the effect of the mutant leaves on rate of dry matter production, rate of leaf area development, assimilation efficiency, and dry matter partitioning during early growth of cotton plants. Three near-isogenic lines of 'Stoneville 7A' (normal, Okra, and Super Okra leaves) were grown in spaced field plantings during 2 years. The two mutant leaf types had significantly lower dry matter accumulation than the normal-leaf type during both years. Values for Okra leaf-plants were intermediate to the normal and Super Okra-leaf plants. Initial size of cotyledons, mean net assimilation rate, and C exchange rate were similar among the leaf types and were not major factors causing the differential growth rates. The mutant types, especially Super Okra-leaf plants, had low dry matter partitioning into leaf area. Relative leaf area growth rate of the Super Okra-leaf plants was 12 to 20% lower than that of the normal-leaf plants. The leaf area partition coefficient of the Super Okra-leaf plants was 11 to 17% less than that of the normal-leaf plants. Values for the Okra-leaf plants were generally intermediate and frequently not significantly different from normal-leaf plants. These factors are primarily responsible for the low growth rate of Super Okra-leaf plants and probably to a lesser extent affect the growth of Okra-leaf plants in a similar manner.

**Additional index words:** *Gossypium hirsutum*, Leaf shape, Okra leaf, Super Okra leaf, Leaf area, Relative growth rate, Net assimilation rate, Dry matter partitioning.

**R**ATE of leaf area development greatly affects the early vegetative growth in crop plants when solar radiation interception and utilization are limiting. Early vegetative growth, in turn, affects subsequent reproductive development. The importance of leaf area development on growth rates of crop plants have been reported (7, 9, 17, 19). Kaplan and Koller (10) found that relative leaf area growth rate ( $R_a$ ) was more important in accounting for differences in growth rate among soybean [*Glycine max* (L.) Merr.] cultivars than  $CO_2$  exchange rate (CER) of leaves.

The mutant Okra and Super Okra-leaf types in cotton (*Gossypium hirsutum* L.) have less leaf area per plant and a lower leaf area index (LAI) than normal leaf types (1, 2, 11, 16). The reduction in leaf area leads to greater irradiance penetration into fully developed canopies of the Okra-leaf types (6). The influence of the mutant leaf types on late phases of growth has been investigated (6, 12, 13, 16). Little information has been reported about the effect of these leaf types on early vegetative growth. The objective of this study was to assess the effect of these mutant leaf types on early growth of cotton.

### MATERIALS AND METHODS

Three near-isogenic lines (Okra, Super Okra, and normal) of 'Stoneville 7A' cotton, developed as previously described (12, 16), were planted on 3 May 1975 and 2 May 1976 at the Univ. of Arizona Campbell Avenue Farm, Tucson, Ariz. The plants were spaced approximately 1 m both within and between rows on a Typic Torrifluent soil. Management practices were used to ensure adequate fertility, weed control, and irrigation for rapid growth. No insecticides were applied and little insect damage occurred.

The experiments were arranged in randomized complete blocks with four replications in 1975 and six replications in 1976. Data were analyzed as a split-plot in time with leaf type as the whole plot and time of sampling as the sub-plot. Four plants were harvested from each plot during four sampling periods in 1975 and six sampling periods in 1976. At each sampling, plant height was determined and the plants were divided into leaves, petioles, and stems. Leaf area was determined with an automatic leaf area meter (Type AAM-S, Hyashi Denko Co., Ltd., Tokyo, Japan). All plant biomass was dried to a constant weight at approximately 70 °C for dry weight determinations.

Formulae used to calculate growth parameters were as presented by Radford (18):

Mean net assimilation rate ( $\overline{NAR}$ ) =  $[(W_2 - W_1)/(A_2 - A_1)] \{(\ln A_2 - \ln A_1)(t_2 - t_1)\}^{-1}$ , g/dm<sup>2</sup>/week.

Mean leaf area ratio ( $\overline{LAR}$ ) =  $[A_2 - A_1]/(W_2 - W_1) \{(\ln W_2 - \ln W_1)(\ln A_2 - \ln A_1)\}^{-1}$ , dm<sup>2</sup>/g, where  $W_1$ ,  $W_2$  and  $A_1$ ,  $A_2$  are total dry weights and leaf areas at times  $t_1$  and  $t_2$ .

Relative leaf area growth rate ( $R_a$ ) and relative growth rate ( $r$ ) were determined from the slopes of regression lines of logarithms of leaf area per plant and total dry weight per plant plotted against time.

<sup>1</sup>Contribution from the Arizona Agric. Exp. Stn., Tucson, Ariz. as Technical Paper No. 3346. Received 4 Aug. 1980.

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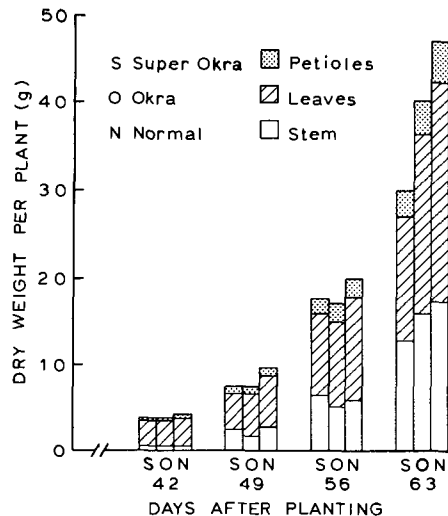


Fig. 1. Dry weight accumulation for normal, Okra, and Super Okra-Leaf cotton plants in the 1975 growing season.

Formulae used to calculate dry matter partitioning were presented by Potter and Jones (17):

Leaf area partition coefficient (LAP) =  $R_a A_o \exp(r_a t) / r W_o \exp(r t)$ ,  $\text{dm}^2/\text{day}/\text{g}/\text{day}$ .

Leaf weight partition coefficient (LWP) =  $R_l L_o \exp(R_l t) / r W_o \exp(r t)$ ,  $\text{g}/\text{day}/\text{g}/\text{day}$ , where  $R_a$ ,  $R_l$  and  $r$  are relative leaf area growth rate, relative leaf weight growth rate, and relative growth rate, respectively.  $A_o$ ,  $L_o$ , and  $W_o$  are extrapolated leaf area, leaf weight, and total dry weight on day of emergence;  $t$  is time in days.

Carbon dioxide exchange rate (CER) was measured on 16 July 1975 using an air-sealed chamber which was a modification of the chamber developed by Wolf et al. (21). The chamber was built of plexiglass with dimensions of  $18 \times 23 \times 5$  cm. The design allowed insertion of a single leaf into the chamber without injury to the petiole. Air samples were passed through high-density nylon tubing to the differential infrared gas analyzer (IRGA, Beckman Model 865-25) located in an air-conditioned instrument trailer. Measurements of photosynthesis were taken during a stable 5-min period when solar radiation was in the range of 1.0 to 1.4  $\text{cal}/\text{cm}^2/\text{min}$  (measured by an Epply pyranometer). The fourth or fifth leaf below the last unrolled leaf on the mainstream was measured on two plants in each plot.

## RESULTS AND DISCUSSION

### Growth Rates and Assimilation Efficiency

Blackman (4) reported that total dry weight (or leaf area) of a plant depends upon (a) the initial size, (b) relative growth rate, and (c) the duration of the growing period. The three leaf types had similar cotyledon area (0.17 to 0.18  $\text{cm}^2$ ), cotyledon weight (0.13 to 0.14 g), and specific cotyledon weight (0.76 to 0.79  $\text{g}/\text{dm}^2$ ) 14 days after planting in 1976. Similar data were not taken in 1975. Initial size, therefore, can be eliminated as a factor in dry weight variation among the leaf types.

The increase in dry weight with time generally followed an exponential growth pattern (Fig. 1 and 2). Spaced planting eliminated interplant competition and allowed a full expression of exponential growth. The normal leaf type had significantly higher total dry weight than Okra

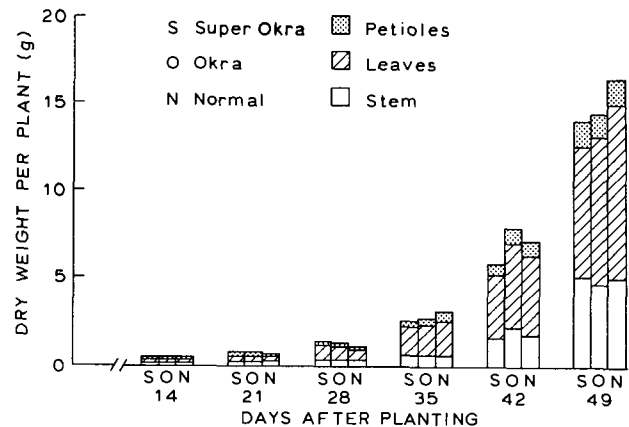


Fig. 2. Dry weight accumulation for normal, Okra, and Super Okra-leaf cotton plants in the 1976 growing season.

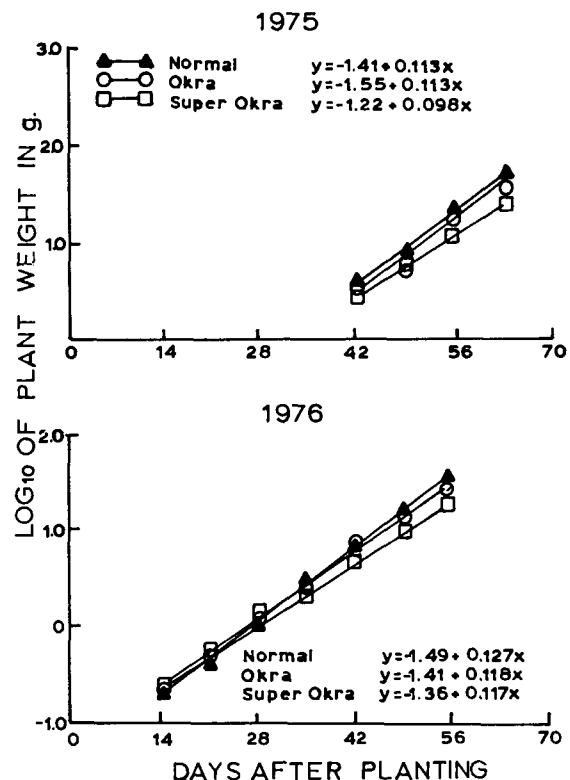


Fig. 3. Logarithmic plot of dry weight accumulation for normal, Okra, and Super Okra-leaf cotton plants [ $y = \log_{10}$  dry weight (g),  $x$  = time after planting (days)].

and Super Okra leaf types by 63 and 49 days after planting in 1975 and 1976, respectively. Weight of the Okra-leaf type was intermediate to Super Okra and normal-leaf plants. The three near-isogenic lines did not differ significantly in plant height at any of the harvests. By 49 days after planting, plant height averaged 24 and 34 cm in 1975 and 1976, respectively.

Low dry matter accumulation by the mutant-leaf types suggests a low relative growth rate ( $r$ ). This trend is shown in the logarithmic plot of dry weight with time in Fig. 3. The slope is an estimate of  $r$ . The slopes were not significantly different at the 0.05 level in an analysis of

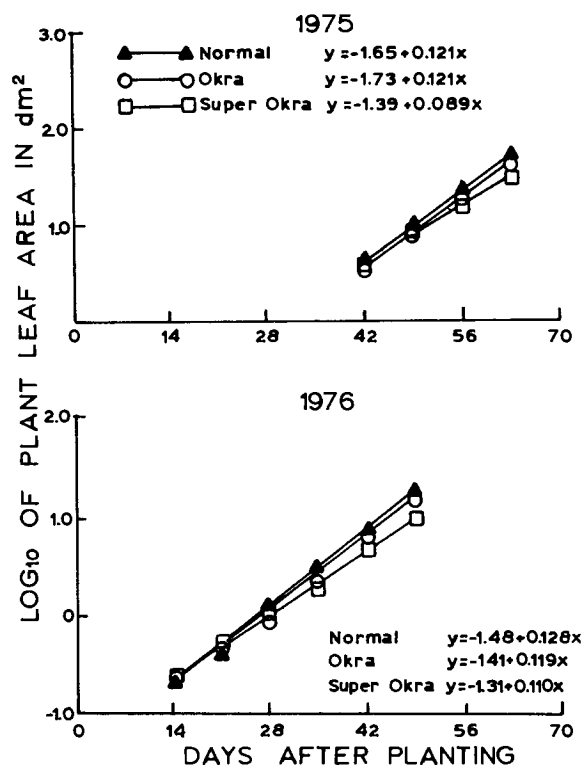


Fig. 4. Logarithmic plot of leaf area development for normal, Okra, and Super Okra-leaf cotton plants [ $y = \log_{10}$  leaf area(dm<sup>2</sup>),  $x$  = time after planting (days)].

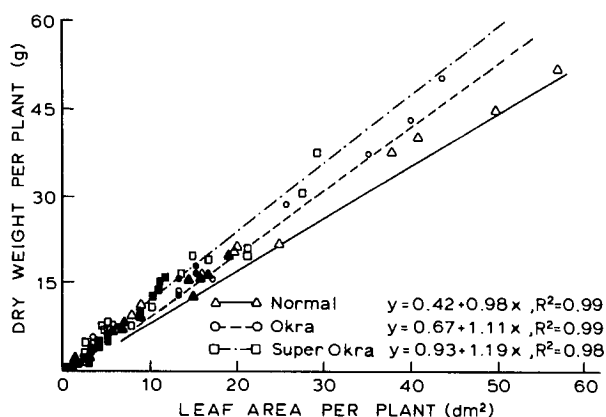


Fig. 5. Relationship between leaf area and dry weight for normal, Okra, and Super Okra-leaf cotton plants [ $y$  = dry weight(g),  $x$  = leaf area(dm<sup>2</sup>)]. Open symbols are for 1975 and closed for 1976.

variance of slopes from individual plots. The normal-leaf type, however, tended to have a higher  $r$  than the Super Okra-leaf type during both years. The data suggest that differences do exist, especially between the growth rate of Super Okra and normal-leaf plants, but was not measured in this study because of inadequate sampling.

Mean net assimilation rate (NAR), which is an index of assimilation efficiency and a component of relative growth rate, was similar among the three leaf types (Table 1). In addition, CER did not differ significantly among the lines when measured in 1975. These values averaged 1.9, 2.1, and 2.1 nmol/sec/cm<sup>2</sup> for normal,

Table 1. Mean net assimilation rate (NAR) of normal, Okra, and Super Okra-leaf cotton plants during two growing seasons.

| Sampling period    | Net assimilation rate   |        |            | Average |
|--------------------|-------------------------|--------|------------|---------|
|                    | Leaf type               |        |            |         |
|                    | Normal                  | Okra   | Super Okra |         |
|                    | g/dm <sup>2</sup> /week |        |            |         |
| 1975               |                         |        |            |         |
| 14 June to 21 June | 0.98 a*                 | 0.89 a | 0.82 a     | 0.89 q  |
| 21 June to 28 June | 0.79 a                  | 0.97 a | 1.08 a     | 0.95 q  |
| 28 June to 5 July  | 0.87 a                  | 0.92 a | 0.66 a     | 0.82 q  |
| Average            | 0.88 m                  | 0.93 m | 0.85 m     |         |
| 1976               |                         |        |            |         |
| 16 May to 23 May   | 0.80 a                  | 0.74 a | 0.80 a     | 0.77 q  |
| 23 May to 30 May   | 0.88 a                  | 0.95 a | 1.01 a     | 0.95 q  |
| 30 May to 6 June   | 1.06 a                  | 0.82 a | 0.90 a     | 0.93 q  |
| 6 June to 13 June  | 0.91 a                  | 1.15 a | 0.93 a     | 0.99 q  |
| 13 June to 20 June | 0.90 a                  | 0.70 a | 1.11 a     | 0.90 q  |
| Average            | 0.91 m                  | 0.87 m | 0.95 m     |         |

\* Values followed by the same letter in a year and letter series are not significantly different at the 0.05 level of probability according to the Student-Newman-Keuls' Test.

Okra, and Super Okra-leaf types, respectively. Elmore et al. (8) also found that CER of Super Okra and broadleaf lines were similar. Mauney et al. (15), however, pointed out that small differences in CER that are difficult to measure can have a large influence on cotton yield. Nevertheless, both our NAR and CER measurements indicate that assimilation efficiency was not a major factor contributing to growth differences among the three leaf types.

#### Dry Matter Accumulation as a Function of Leaf Area

Leaves are the most active photosynthetic organs in crop plants and the main site of dry matter production which has led some researchers to stress the importance of leaf area development as an important factor in crop yield (3, 20). Leaf area of the three leaf types was similar early in the season, but the effect of leaf shape became apparent as the season advanced. The slopes of the regression lines in Fig. 4 are estimates of leaf area growth rates ( $R_a$ ). In an analysis of variance using slopes of individual plots, the normal and Okra-leaf types had significantly higher  $R_a$  than the Super Okra-leaf type in both 1975 and 1976. We believe that sufficient samples were not taken to show the differences that exist between the normal leaf and Okra-leaf plants. Variation in biomass production among the leaf types, however, was related to variation in rate of leaf area expansion since there was no significant variation in assimilation properties among the three leaf types.

Super Okra and Okra-leaf types had significantly higher slopes than the normal-leaf type (Fig. 5). In addition to differences in dry matter partitioning among aerial plant parts, high total dry weight per unit leaf area by the mutant-leaf types may be related to less biomass partitioning to the roots. Root weights were not measured in this study, but Brouwer (5) reported that a functional equilibrium between the size and activity of root and shoot systems is maintained by plants in their exponential phase of growth. Young apple (*Malus domestica* L.) trees with reduced leaf area were reported in a study by Maggs

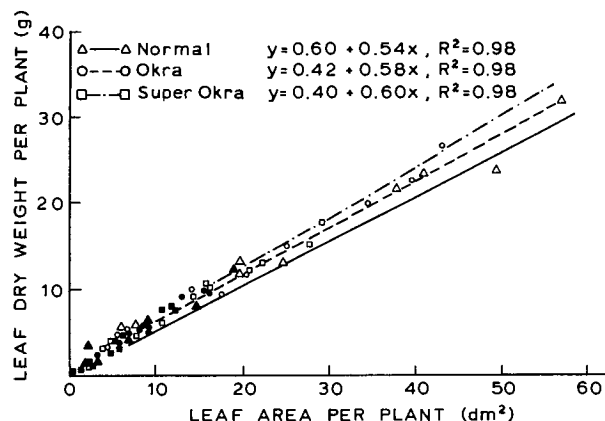


Fig. 6. Relationship between leaf area and leaf weight for normal, Okra and Super Okra-leaf cotton plants [ $y$  = leaf weight(g),  $x$  = leaf area(dm<sup>2</sup>)]. Open symbols are for 1975 and closed for 1976.

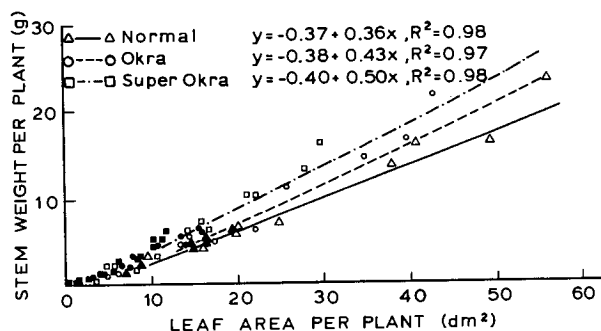


Fig. 7. Relationship between leaf area and stem dry weight for normal, Okra and Super Okra-leaf cotton plants [ $y$  = stem weight (g),  $x$  = leaf area(dm<sup>2</sup>)]. Open symbols are for 1975 and closed for 1976.

(14) to have higher shoot-to-root ratios than unpruned trees.

The relationship was also linear between leaf area per plant and leaf dry weight per plant and leaf area per plant and stem dry weight per plant (Fig. 6 and 7). There was more divergence among the leaf types in stem weight per unit leaf area than leaf weight per unit leaf area. Thus, most of the difference among the leaf types in aerial dry weight at a given leaf area was due to difference in stem weight rather than in leaf weight.

#### Dry Matter Partitioning

Growth of plants can be separated into accumulation of photosynthate and partitioning of photosynthate into various plant parts (8). An analysis of investment of daily dry matter increase into leaf area expansion can lead to establishment of a cause-effect relationship between leaf area and vegetative growth.

Mean leaf area ratio expresses the amount of leaf area developed per unit plant weight and is a component of relative growth rate. During both years, LAR was similar early and diverged as the season progressed (Fig. 8). The normal-leaf type had a significantly higher LAR than the Super Okra-leaf type for the periods 56 to 63 days and 42 to 49 days after planting in 1975 and 1976, respectively.

Table 2. Leaf area partition coefficient (LAP), and leaf weight partition coefficient (LWP) for normal, Okra, and Super Okra-leaf cotton plants in 1975 and 1976.

| Leaf type  | LAP                            |         | LWP             |        |
|------------|--------------------------------|---------|-----------------|--------|
|            | 1975                           | 1976    | 1975            | 1976   |
|            | (dm <sup>2</sup> /day)/(g/day) |         | (g/day)/(g/day) |        |
| Normal     | 0.83 a*                        | 0.98 a  | 0.69 a          | 0.48 a |
| Okra       | 0.80 a                         | 0.96 ab | 0.69 a          | 0.53 a |
| Super Okra | 0.69 b                         | 0.88 b  | 0.67 a          | 0.39 a |

\* Means within a column followed by the same letter are not significantly different at the 0.05 level of probability according to the Student-Newman-Keuls' Test.

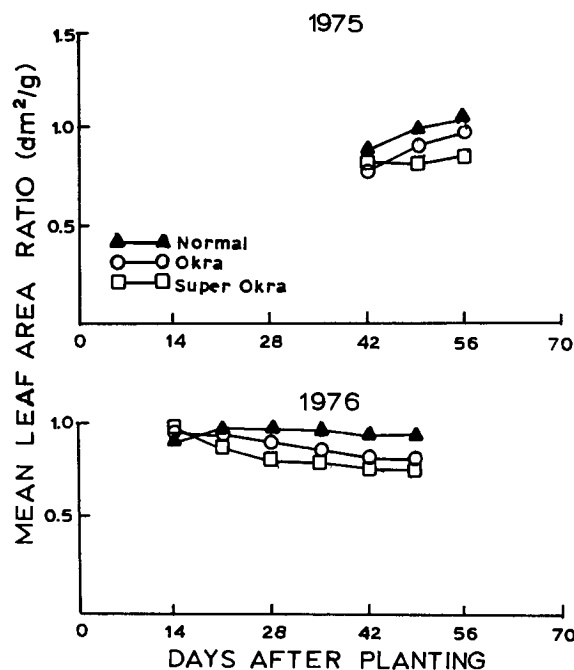


Fig. 8. Mean leaf area ratio of normal, Okra, and Super Okra-leaf cotton plants in 1975 and 1976.

Leaf area partition coefficient (LAP) and leaf weight partition coefficient (LWP) are estimates of dry matter partitioning rates into leaf area expansion and leaf weight increase, respectively. The normal and Okra-leaf types had significantly higher LAP than the Super Okra-leaf type in 1976 with the Okra-leaf type intermediate in value.

Leaf weight partition coefficient (LWP) did not vary significantly among the three leaf types in either 1975 or 1976 (Table 2). The high LAR and LAP of normal and Okra-leaf types reflect the higher dry matter investment into leaf area development by these leaf types than by the Super Okra-leaf type. Potter and Jones (17) showed that  $NAR \times LAP = R_a$ . Since mean net assimilation rate (NAR) was similar among the three leaf types, variation in  $R_a$  among the leaf types is related directly to differences in the fashion in which the leaf types partition dry matter into leaf area expansion. The mutant leaf shapes are not expressed visually in the first few leaves developed in seedlings and the climax leaf forms do not

appear until later in the season. This progressive change in leaf form is reflected in the observed differences in LAP.

The lack of significant differences in LWP among the three leaf types indicates that the investment of dry weight per se into leaves is not as important as the investment into leaf area. This is in agreement with Potter and Jones's (17) conclusion that dry matter partitioning into leaf weight is a poor index of potential growth.

## CONCLUSION

Our study has shown that the mutant-leaf shapes, Okra and Super Okra, reduce the growth rate of young cotton plants as measured by dry weight increase, but have little effect upon early expression of plant height. Differences in rate of biomass accumulation are not related to initial plant size at emergence nor to differences in assimilation efficiency, but are caused by differences in dry matter partitioning as the young plants grow. During growth, the mutant-leaf plants partition a lower percentage of dry weight into leaf area than do the normal-leaf plants. Low  $R_a$  and LAP of the Super Okra-leaf plants particularly contribute to their low growth rate. Relative leaf area growth rate ( $R_a$ ) of the Super Okra-leaf plants was 20 and 12% less than that of the normal-leaf plants in 1975 and 1976, respectively. At the same time, the leaf area partition coefficient (LAP) of the Super Okra-leaf plants was 17 and 11% less than that of the normal-leaf plants. Values of the Okra-leaf plants were intermediate and frequently not significantly different from the normal-leaf plants.

Rate of leaf area expansion should be considered in any effort to improve early growth rates of these mutant-leaf types for further commercial use. Selection for faster leaf area growth rather than a higher net assimilation rate should be of value for enhancing early vegetative growth, especially of the Super Okra-leaf mutant. At later reproductive stages, partitioning of only small amounts of dry matter to leaf area is desired, especially with narrow-row culture (13). Thus, it would be desirable to identify genetic material that does not express the mutant leaf form until after plants begin reproductive development. The degree of expression desired would depend upon the row spacing in which the plants were to be grown. With narrow-row culture, a rapid development into the single lobe climax of the Super Okra would be desired soon after the plants enter into the reproductive stage. With normal row spacing where more solar radiation can penetrate into the plant canopy, the mutant expression should be slower with a climax form that is not as extreme.

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