YRB 59-04

REPORT ON OBJECTIVE COTTON YIELD STUDIES

These studies were started in 10 Southern States during the 1954 growing season and have been conducted every year since that time. In 1954, the sample consisted of 2[illegible]0 cotton fields allocated to various parts of the region in proportion to the cotton acreage. In 1955, the sample of fields was doubled, but the increase was effected by taking two fields per farm without increasing the total number of farms covered. In 1956 and 1957, the sample consisted of 1,[illegible]00 cotton fields allocated to the 10-State region approximately in proportion to the cotton acreage but with a minimum number of fields assigned to individual States so that differences in plant behavior from one State to another could be detected. In 1958, the sample was reduced to about 800 fields.

Plant observations are made as of August 1, September 1, October 1 and a post-harvest survey is made on as many of the fields as possible after farmers harvested the fields. In 1954, no counts were made on October 1.

The Forecasting Procedure

As of August 1, many plants do not yet have their full set of fruit and it is necessary to forecast the total number of bolls still to be formed. In making such a forecast, the first step is to forecast a maximum fruit load, which includes fruit in all stages of maturity: squares, blooms and small bolls, and large bolls. Blooms are combined with small boll because the cotton blossom lasts only a very few days. Blooms and all bolls less than one inch in diameter are classified as small bolls. Large bolls consist of all unopened bolls one inch or more in diameter, all open bolls, and bolls from which cotton was already picked.

Studies on the growth of the cotton plant made in previous years indicate that the average plant showing squares, but no blooms or bolls, is carrying about one-fourth of its maximum fruit load. The average plant that has started to bloom, but is not yet carrying any large bolls, has three-fourths of its full load. The average plant that is already carrying some large bolls has its maximum load. Although such plants will continue to form new fruit, any additions are offset by shedding, so there is no net gain in the total. Most shedding is of immature fruit.

By classifying all sample fields into these maturity categories on the basis of the kind of fruit observed in the sample plots, and making use of these relationships, it is possible to compute the expected maximum fruit load from the August 1 field observations. This maximum fruit load also provides an indication of the weekly rate at which fruit is being formed as of August 1. That fruiting rate is computed by assuming that the weekly rate at which fruit is being set is equal to one-sixth of the maximum fruit load for plants which do not yet show large bolls and is equal to zero for plants that are already carrying large bolls. There is a fairly close relationship between the weekly fruiting rate computed in this manner and the total increase in blooms and bolls set between August 1 and September 1. For the region as a whole, the pertinent data are shown in Table 1. All data are in terms of 10 feet of cotton row.

Table 1.--Relationship between August 1 weekly fruiting rate and blooms and bolls set between August 1 and September 1.

Year	Computed maximum fruit load	Computed fruiting rate	Blooms and bolls set Aug.1-Sept. 1
	Number	No. per week	Number
1954	144	6.0	17.4
1955	170	13.1	39.3
1956	158	10.3	21.4
1957	215	18.4	45.0
1958	214	17.2	52.1

The additional number of blooms and bolls to be formed between August 1 and September 1 is computed from this relationship on August 1 and added to the total number of blooms and bolls already on the plants to derive an estimate of the total blooms and bolls expected by September 1. The September 1 bloom and boll count is important because in the 10 Southern States the blooms and bolls present on that date determine practically all of the final crop. Any squares that may be set after September 1 have little likelihood of producing cotton by harvest time.

During the first two years of these studies, computations were made from pooled data for the region as a whole. But after the sample size was increased sufficiently to indicate differences between States, it became apparent that the relationship between the weekly fruiting rate and the number of blooms and bolls set between August 1 and September 1 varied considerably from one State to another. In fact, east and west Texas behave so differently that those two strata also need to be treated as separate "States." Charts have now been prepared that show relationships such as those in Table 1 separately for groups of States that appear to behave approximately alike. The behavior of the boll counts from month to month for the period 1955-1958 is shown in Table 2 for the 10-State region as a whole. Post-harvest data are not yet available for 1958. All counts are in terms of fruit per 10 feet of row.

Table 2.--Bloom and boll counts per 10 feet of row by months

Year	August 1			September 1			October 1					
	Blooms & bolls present	Blooms & bolls to be set	Total bolls expected	Large bolls	Blooms & small bolls	Total blooms & bolls	Large bolls	Blooms & small bolls	Total blooms & bolls	Large bolls	Rotten bolls	Total bolls
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
1955	43.8	39.3	83.0	58.5	24.8	83.3	75.3	4.4	79.7	5.5	4.4	9.9
1956	50.0	30.5	81.0	61.8	11.5	73.3	67.0	11.9	78.9	4.9	5.6	10.5
1957	45.0	40.5	85.5	56.8	33.0	89.8	78.0	20.5	98.5	7.8	9.5	17.3
1958	46.6	47.4	94.0	67.5	33.8	101.3	83.5	10.5	94.0	--	--	--

The large bolls counted in the post-harvest survey include all open bolls still on the plants and all bolls that grew to full size but never opened. "Rotten" bolls include all bolls that were rotted, withered, diseased, or badly damaged. Up to the present time, boll counts have been translated into yield indications by assuming an average survival rate for all bolls present on September 1. For the August 1 forecast that survival rate is applied to the total bolls expected by September 1. For the October 1 forecast an average survival rate is also used, but the mortality of bolls between October 1 and harvest is assumed to be only one-half as large as the mortality between September 1 and harvest.

The loss of cotton caused by failure of bolls to reach maturity has been expressed in terms of pounds of lint per acre. That estimate was derived by weighing open cotton still in the fields at the time of the post-harvest surveys and expressing the weight of that cotton in terms of the number of open bolls present. That weight per boll is less than the season average weight of lint per boll for harvested cotton because late maturing bolls are smaller than average. It was assumed that all bolls failing to open or to mature for any reason, but which were still on the plants after harvest, would have produced the same amount of cotton per boll as the open bolls still on the plants if they had reached maturity. The total amount of lint represented by all unopened and "rotten" bolls still on the plants was then expressed in terms of pounds of lint per acre. These losses of potential yield are shown in Table 3 for the years 1954-1957.

Table 3.--Cotton not harvested or lost because of failure of bolls to reach maturity

Year	Loss of potential yield
	Pounds of lint per acre
1954	28
1955	33
1956	48
1957	72

The large loss occurring in 1957, which is also reflected in the number of unopened bolls found on the plants in the post-harvest survey, was caused by the prolonged wet weather during the last half of the 1957 growing season.

Now that detailed data for several years are available, we are in process of studying the survival rates of bolls more thoroughly. It is apparent that applying an average survival rate to the total boll count on any forecast date is not too satisfactory. The percentages of large and small bolls vary considerably from State to State and from year to year within a State. It seems reasonable that large bolls have a greater chance of surviving than small bolls. The following equations show the relationship, by States, between the number of large bolls present on October 1 and the
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September 1 counts of large and small bolls. In those equations, Y represents the October 1 large boll count, X_1 the September 1 large boll count, and X_2 the September 1 small boll count.

Table 4.--Contributions of large and small bolls counted on Sept. 1 to Oct. 1 large boll count.

State	Relation of Oct. 1 large boll count to Sept. 1 count of large and small bolls
Ala.	$Y = X_1 + 0.34\ X_2$
Ark.	$Y = X_1 + 0.62\ X_2$
Ga.	$Y = X_1 + 0.00\ X_2$
La.	$Y = X_1 + 0.50\ X_2$
Miss.	$Y = X_1 + 0.45\ X_2$
N. C.	$Y = X_1 + 0.23\ X_2$
Okla.	$Y = X_1 + 0.81\ X_2$
S. C.	$Y = X_1 + 0.22\ X_2$
Tenn.	$Y = X_1 + 0.63\ X_2$
Tex.	$Y = X_1 + 0.74\ X_2$

In these equations, it was assumed that all large bolls present on September 1 would still be on the plants on October 1. That is not strictly true, but if a multiple regression equation which allows for some possible mortality of large bolls had been fitted to the data for individual States, sampling errors in the resulting net regression coefficients would have been so large that unrealistic coefficients would have been obtained in some instances. The equations in Table 4 are believed to be more realistic than any that would have been obtained by allowing for a possible mortality of large bolls.

These equations have not yet been used in any of our current experimental forecasts. The procedure followed to date for an August 1 yield forecast has been to forecast the total number of bolls expected by September 1 and to assume that 90 percent of those bolls represent cotton going to the gin. For a September 1 forecast, the actual count of all bolls present by that date is used in the same way. For an October 1 forecast, only large bolls present by that date are assumed to contribute to the final yield and it is assumed that 95 percent of those bolls go to the gin. The equations in Table 4 indicate that the September 1 forecast would be improved by allowing for differences in the survival rates of small bolls from one State to another. The August 1 forecast could also be improved if it is possible to break the August 1 forecast of number of bolls expected to be present by September 1 into separate forecasts of large bolls and small bolls. Studies in that direction are now being undertaken.

To compute yield from a boll count, we need to know the average amount of lint produced per boll. Ever since these studies were started, field workers were instructed to pick all open cotton in the sample plots on every visit to the sample fields and to weigh it in the field. A small part of that cotton is taken to the office and dried at room temperature to get the net weight of seed cotton per boll. The weight of seed cotton is adjusted to a corresponding weight of lint by assuming that 37 pounds of lint will be ginned from every 100 pounds of seed cotton. As these studies progressed, it has become apparent that open cotton picked early in the season generally yields more cotton per boll than cotton picked later in the season. As the monthly visits to the sample fields are terminated after October 1, all cotton weighed up to that time usually averages out to a higher weight per boll than the true season average. However, there appears to be a fairly consistent relationship between the average weight per boll for all cotton picked up to any specified date and the percentage of the total crop that has opened by that date. All of our boll weights from 1954 to 1958 have now been adjusted to a season average basis by that method.

There appears to be some correlation between the amount of cotton produced per boll and the maximum fruit load. As the maximum fruit load can be forecast as early as August 1, this correlation provides a basis for forecasting boll weight early in the season. These relationships have not yet been established for individual States. As our computations are made State by State, and average boll weights are consistently higher in some States than in others, we have followed the practice of using State average weights for previous years in our experimental yield forecasts without attempting to use forecasts of boll weights.

For the region as a whole, the estimated season average boll weights are shown side by side with the August 1 estimates of maximum fruit load for 1954-1958.

Table 5.--Relationship of season average boll weight to August 1 estimated maximum fruit load

Year	Maximum fruit load	Seed cotton per boll
	Number	Grams
1954	144	4.62
1955	170	4.83
1956	158	4.61
1957	215	4.83
1958	214	4.86

The maximum fruit load is expressed in terms of total numbers of fruit in all maturity stages per 10 feet of cotton row.

August 1 Yield Forecasts

As indicated in the previous section, an August 1 yield forecast is derived by using the observed fruit counts and maturity classifications of fields to compute an estimate of the total number of blooms and bolls expected to be present in an average 10 feet of row on September 1. An estimate of the amount of cotton produced per boll is applied to that count to derive a forecast of gross yield per acre, which contains no allowances for boll mortality or harvesting losses. From experience obtained in the first few years of this work, it is assumed that 90 percent of that gross yield will actually be ginned. The net indicated objective yield is 90 percent of the indicated gross yield. Such forecasts are shown in Table 6, which also gives comparisons with current Crop Reporting Board forecasts made on August 1 of each year.

Table 6.--August 1 Yield Forecasts, 1954-1958

Year	Fruit counts			Blooms and bolls to be set: Aug. 1-Sept. 1	Total Sept. 1 blooms and bolls	Indicated yield per acre	
	Large bolls	Blooms & sm. bolls	Squares			Objective	Board
	No.	No.	No.	No.	No.	Pounds	Pounds
1954	22.5	28.8	73.5	18.0	69.3	286	274
1955	20.3	23.5	85.0	39.2	83.0	383	329
1956	21.0	29.0	86.0	31.0	81.0	382	346
1957	21.2	23.8	108.8	40.5	85.5	389	358
1958	18.8	27.8	131.2	47.4	94.0	421	393
1959						441	411

The first 3 columns of this table give the August 1 fruit counts for fruit in each stage of maturity. The fourth column shows the estimated number of additional blooms and bolls to be set between August 1 and September 1. That figure must be added to the data in the first 2 columns of the table to obtain the total number of blooms and bolls expected in an average 10 feet of row on September 1.

As indicated previously, the forecast of blooms and bolls to be set between August 1 and September 1 has not been made from exactly the same formulas each year. Estimates for 1954 and 1955 were computed from relationships observed in the first two years. In 1956, when the sample was enlarged, charts were prepared for individual States. These were used in 1956. In 1957 and 1958, additional data obtained in previous years were used to refine the charts. If all data now available were used to re-compute the forecasts for all years from 1954 through 1958, some changes could be expected in the estimates appearing in the fourth column of Table 6 and in indicated yields appearing in the sixth column.

It is of some interest to compare the estimates in the fourth column with the actual counts of blooms and bolls set between August 1 and September 1, as shown in the last column of Table 1. It appears that fairly accurate forecasts of the total set of blooms and bolls can be obtained as early as August 1.

September 1 Yield Forecasts

The September 1 forecasts were made in exactly the same fashion as the August 1 forecasts, except that all blooms and bolls were assumed to be present by that date. Any squares that may have been on the plants were disregarded because only bolls and blooms were expected to contribute to the final yield. Past average boll weights, and a 10 percent deduction for harvesting losses and boll mortality, were applied to the total boll and bloom counts shown in the table to arrive at the objective yield indications. The pertinent data per 10 feet of row and the objective yield indications are shown in Table 7, together with official forecasts made on those dates.

Table 7.--September 1 Yield Forecasts, 1954-1958

Year	Fruit counts			Indicated yield per acre	
	Large bolls	Blooms & sm. bolls	Total	Objective	Board
	No.	No.	No.	Pounds	Pounds
1954	56.5	12.0	68.5	298	251
1955	58.5	24.8	83.3	389	336
1956	61.8	11.5	73.3	350	351
1957	56.8	33.0	89.8	405	391
1958	67.5	33.8	101.3	454	418
1959				449	

October 1 Yield Forecasts

The October forecast has been based entirely on the large bolls counted as of that date under the assumption that any fruit in an earlier stage of maturity would not be likely to produce cotton for harvest. But as October 1 is fairly close to harvest, it was assumed that 95 percent of the large bolls present on October 1 would go to the gin. Only a 5 percent deduction, rather 10 percent, is made from the gross yield indicated by the large boll count and the average weight of cotton per boll. The results are shown in Table 8.

Table 8.--October 1 Yield Forecasts, 1954-1958

Year	Large bolls	Indicated yield per acre		
		Objective	Board	Board final
	No.	Pounds	Pounds	
1954	No survey	--	--	--
1955	75.3	372	369	331
1956	67.0	333	357	360
1957	78.0	379	378	331
1958	83.5	404	397	--
1959		433	404	

The final Board estimate of yield per acre is shown in the last column of the table. The final figure for 1958 is not yet available. In 1957, the large difference between the official final estimate and the October 1 official forecast was caused by severe deterioration of the crop from prolonged wet weather during the latter part of the growing season.

At the time the October 1 boll counts are made some fields have already been partially picked so that some of the total bolls available for harvest are no longer in the fields but have already been harvested. Counts of such bolls are supposed to be included in the large boll count in Table 8. For the first few years, attempts were made to arrive at a count of bolls already picked by counting the burrs on the sample plants. It is believed that some burrs were missed by this process because they disappeared from the plants after the cotton was picked. The procedure now followed is to pick off the entire burr whenever open cotton is picked on a visit to the sample plots. A record is kept of all bolls picked and that count is added to the count of bolls still present on subsequent visits.

Post-harvest Survey

After farmers harvest the fields, as many sample fields as possible are gleaned to get counts of open cotton bolls that were not harvested, healthy unopened large bolls, and bolls that were rotten, dried-up, or unhealthy in other respects. The estimates of harvesting loss and losses from boll mortality shown in Table 3 were computed by assuming that the equivalent weight of cotton per boll for all bolls counted on the post-harvest survey would be the same as for open bolls found on that date. The counts are shown in the last 3 columns of Table 2. The higher than average loss in 1957 was caused by the wet weather prevailing during September and October in that year.

Studies on Irrigated Cotton in California and Arizona

Two years' data are now available on irrigated fields in California and Arizona. These studies have been aimed at developing a forecasting model for cotton grown under such conditions. Results to date indicate that the fruiting habit of the plant is somewhat different for cotton grown on irrigated land than in the 10-State Southern region. Maturity observations related to fruit counts indicate that plants showing only squares have about 10 percent of a full fruit load, plants showing small bolls but no large bolls are carrying about 20 percent of a full load, plants showing large bolls but no open bolls carry about 70 percent of a full load, and plants showing open bolls have about all the fruit that will contribute to the final yield. All of the fruit that contributes to the final yield is not set on the plants until about October 1, as contrasted with September 1 for dry-land cotton. There appears to be about a 7 to 8 percent loss of yield potential between October 1 and November 1.

These studies are being continued to establish the fruiting pattern of the plant more exactly. There have been instances of erratic behavior in the relationship between the boll counts, the number estimated to reach maturity by harvest time, and the numbers actually harvested. Part of the difficulty may be due to errors in counting fruit.

Conclusion

The analyses reported herein have been based upon computations made currently each year, after a basic model was derived from 1954 and 1955 data in the 10 Southern States. Some refinements were introduced each year, but no revisions were made in previous years' computations. The forecasts made in any year were based only upon information that was available up to that time. The next step in the analysis should logically take the form of revising all earlier computations in the light of all experience gained to date. The results in some tables of the present report could then be expected to be different. If all of the relationships that are now known had been known in the earlier years, the results could logically be expected to differ from those obtained at the time.

One pertinent refinement that needs to be introduced is the use of differential survival rates for large bolls and small bolls counted as of a given forecast date, rather than applying an average allowance for losses to bolls in all categories combined. It appears that allowances for losses made on September 1 have not been sufficiently large. Part of the difficulty may be caused by a greater proportion of small bolls being encountered in the early-season counts in recent years than in the first two years when the forecasting model was derived. Another point that needs investigation is the source of the dead bolls found in the post-harvest surveys. There is reason to suspect that most of the dead bolls found after harvest come from bolls that were in the small-boll category on October 1, or perhaps even on September 1. It is for this reason that experimental October 1 objective forecasts have been based mostly on the large bolls present on that date, with little attention being paid to the small-boll count.