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is considered, however, the measures of relative contribution change to 56 percent for acreage changes and 44 percent for yield changes. The reason is that, owing to a sharp cut in allotments in 1955, harvested acreage dropped from 421,000 to 311,000 acres, a decline of 26 percent. Average yield per acre changed only 5 percent, declining from 1,586 pounds to 1,513 pounds.

Illustration of Use of Proposed Method

Method 3 was used to ascertain the relative effects of acreage and yield changes on year-to-year changes in production of cotton, wheat, and soybeans during the periods 1921–38 and 1939–56. The crops and the periods were selected to illustrate application of the proposed computational method; analysts who are working in these commodity areas may wish to examine other periods. Results of the analysis are shown in table 2.

Results for wheat confirm Meinken's finding that yield changes exerted the predominant influence on yearly changes in production in the period 1920–38. For the period following 1938, however, results show a greater influence of acreage changes than was found by Meinken, probably because of inclusion of 1955, when harvested acreage declined substantially from the previous year.

The analysis of cotton showed that in the period 1921–38 approximately 60 percent of the annual changes in production was attributable to changes in yield. In 1939–56, this contribution dropped to about 30 percent, whereas that of acreage changes rose to about 70 percent. During the more recent period, there were sharp fluctuations in harvested acreage of cotton, particularly in 1947, 1949, 1950, 1951, and 1954, when annual changes ranged from 20 to more than 50 percent. These sharp changes were chiefly the result of a postwar expansion in acreage and the operation of acreage controls in 4 of the 7 years 1950–56.

In the case of soybeans, the analysis showed that in both periods acreage changes were the predominant influence on changes in yearly production, but that the relative contribution of changes in yield was greater in the more recent period than in the earlier one.

Preliminary Report on Objective Procedures for Soybean Yield Forecasts

By Bruce W. Kelly

As part of its expanded research program, the Agricultural Estimates Division of AMS is exploring the possibilities of objective forecasts of yield for several crops. This paper summarizes results obtained from the first year's work on soybeans. Although these results must be regarded as tentative until more data become available, they nevertheless illustrate how the problem is being attacked.

TO DEVELOP TECHNIQUES for forecasting the yield of a crop, it is convenient to study individual components of yield separately. In our study of soybeans, the components considered were the number of plants per acre, the number of pods per plant, and the weight of beans per pod.

This preliminary report is restricted to forecasting the number of pods per plant that will reach maturity and be present on the plants at harvest time, based on 1956 data. As the number of plants per acre can be estimated from sample plots within fields, this is equivalent to forecasting the number of pods per acre.

As for cotton, a forecast made early in the season must allow for fruit not yet on the plants.[1] This is the situation with soybeans on August 1, which is the earliest forecast date considered here. The general approach used in this study was the same as for cotton—namely, to count the pods already present on August 1 and to seek an observable syndrome of plant characteristics that indicates what fraction of a 100-percent load is represented by that count. Again, as with cotton, all pods that will contribute to the final yield have

[1] See HENDRICKS, WALTER A., and HUDDLESTON, HAROLD F. OBJECTIVE ESTIMATES OF COTTON YIELD. Agricultural Economics Research. 9:20–25. 1957.

been formed by September 1. On and after that date, the problem is reduced to estimating the fraction that will survive and reach maturity. (The problem of estimating normal harvesting losses is not considered in this report.)

Two sets of data were available for this study. For the first set, intensive counts of bloom and pod were made at frequent intervals between June 28 and September 11, 1956, on 3 plants in each of 12 Illinois soybean fields near Springfield. This field work was done under direction of the State statistician's office in Springfield. These counts were used to study the growth and fruiting habit of the soybean plant, and to set up a forecasting model. A second set of fruit counts was available from a probability sample of 150 soybean fields dispersed over the producing area in the North Central States. In those fields, counts were made at monthly intervals during 1956 from August 1 until harvesttime. (Only half of these fields were used on August 1.) Relationships derived from the Illinois data were applied to data from the more extensive surveys in the North Central States to test the accuracy with which the final mature pod count could be forecast at the official monthly forecast dates, starting with August 1.

Relationships Observed in Illinois Data

For each plant on which detailed counts could be made throughout the entire growing season, the number of pods present on each date was expressed as a percentage of the maximum number formed on any later date. As there was some variation in the date on which the maximum pod load was attained, the time scale was adjusted so that August 5 was arbitrarily substituted for the actual date. The dates of the other observations were adjusted accordingly. This had the effect of putting the pod counts on a comparable age-of-plant basis. Average percentage of maximum pod load by adjusted dates after these adjustments were made is shown in table 1.

Plotting the relative pod load against time on a chart shows that the decline in pod load proceeds in almost linear fashion after the maximum is reached. The rate of pod formation up to the maximum count follows a typical sigmoid growth curve. The problem in that part of the fruiting history of the plant is to find some observable plant characteristics that are related to the relative

TABLE 1.—*Pod load on soybean plants as percentage of maximum load (Illinois data)*

Adjusted date	Pod load
	Percent
June 28	0. 0
July 11	6. 2
July 17	20. 2
July 28	81. 0
August 5	100. 0
August 28	87. 5
September 11	77. 1

pod load so that when pods are counted it will also be possible to ascertain the fraction of a full load that the count represents.

The Illinois data indicate that plants have their maximum number of blooms about 2 weeks after blooming begins. Pods begin to set at that time. About 2 weeks later, plants carry about half of their fruit as blooms and half as pods. The older pods have already reached full length. In terms of blooms and pods combined, the plant has its maximum fruit load 1 week later, and the presence of beans can be detected in the older pods. Another week later—this would be 4 weeks after pods begin to set—the plant is carrying its maximum number of pods. By the time flowering ceases—about 3 weeks after the maximum pod load has been attained—the plant has shed 13 percent of its pods. Another 16 percent of the pods disappear between cessation of blooming and maturation of pods, so that only about 71 percent of the pods present at the date of maximum pod load are present at harvesttime.

On the basis of these observations, it was concluded that plants on which no pods have yet begun to set at the time of an early-season forecast date, such as August 1, have 0 percent of their maximum pod load; the average plant carrying more blooms than pods has 15 percent of that maximum; the average plant carrying more pods than blooms, but no pods yet showing bean formation, has 75 percent of its maximum; and the average plant showing pods with beans, even if blooms are also present, already has 100 percent of its maximum total per load.

This tentative relationship between observable plant characteristics and relative pod load was applied to August 1 data from extensive surveys conducted over the soybean-producing areas of 11 North Central States. Losses of pods between the

TABLE 2.—*Computation of average percentage of full load present on August 1*

	Relative number of fields	Percentage of maximum pod load
	Percent	*Percent*
No pods set	11	0
More blooms than pods	24	15
More pods than blooms	37	75
Some pods having beans	28	100
Weighted average	100	59.4

date on which the maximum count was reached and harvesttime were also assumed to be of the same relative size as in the Illinois data.

Analysis of Data From North Central States

Observations in the North Central States were made at monthly intervals on two sample plots in each sample field. Each plot consisted of two adjacent row sections, 3 feet in length. All soybean plants were counted in each plot, but pods were counted on only 1 of the 2 row sections in each plot. Detailed counts of blooms, pods, nodes, and lateral branches were made on one plant adjacent to each row section on which pods were counted. These detailed counts were used to classify fields by stage of maturity into the categories suggested by the Illinois data. This classification was used to estimate the percentage of the maximum pod load that was reprsented by the August 1 pod count.

The classification of fields, the relative pod load for each class, and the weighted average relative pod load for all fields in the survey, are shown in table 2.

In the August 1 survey, the average pod count was 798 per 6 feet of row. The corresponding counts on later surveys were 1,198 on September 1 and 946 on October 1.

As of August 1, the maximum pod count that would be obtained can be forecast by dividing the observed count on that date by the fraction of a full load represented by that count: 798/0.594= 1,343. This is larger than the number observed on September 1, but the Illinois data indicate that about 13 percent of the maximum pod load is lost between August 1 and September 1. The number of pods expected to be present on September 1 should be (0.87) (1,343) = 1,168 per 6 feet of row. This agrees remarkably well with the 1,198 actually observed on September 1. Again, according to the Illinois data, the number of pods found on October 1 should be about 29 percent less than the maximum: (0.71) (1,343) = 954. This also agrees closely with the 946 actually counted on October 1.

It thus appears that a forecast of the number of pods that will be present at harvest time can be made as early at August 1. That forecast is obtained in two stages. First, the maximum potential pod load is computed from the number already present and the indicated percentage of a full load represented by that count. The number of these pods that will be present at harvesttime is then computed from the average survival rate.

By September 1, most plants have stopped blooming, very few new pods are being formed, and beans are developing in most pods on the plants. For a September 1 forecast of pods present at harvesttime the problem is mainly to estimate subsequent losses. These losses can be estimated from trends such as those observed in the Illinois data. But there may be other possibilities. For example, it was observed that for plants that have stopped blooming by September 1, the ratio of the October 1 pod count to the September 1 count was identical with the ratio of the September 1 count of pods with beans to the September 1 total pod count. For the region as a whole, the October 1 pod count was 79.0 percent of the September 1 count. The September 1 ratio of pods with beans to total pods was 80.9 percent. The agreement is also fairly good when considered State by State. This implies that plants mature enough to stop blooming at that stage, are carrying all pods that will produce beans and that pods in excess of that number are likely to be shed by the plants.

Experimental work is continuing to test the validity of the relationships described here and to seek possible refinements. For the August 1 forecast, some other basis for classifying plants according to maturity may be more suitable. For the September 1 forecast, the behavior of some plants that are still setting pods needs to be studied. Weight of bean is receiving attention. Harvesting losses are being estimated by gleaning sample fields after harvest.