RELATIONSHIP BETWEEN YIELD AND FINAL PLANT MAP DATA IN ACALA COTTON

R. E. Plant, M. Keeley, D. Munk, B.A. Roberts, R.K. Vargas , B.L. Weir, and S. Wright
University of California, Davis, CA

Abstract

The objective of this paper is to compare four methods of estimating yield on a field-by-field basis using final plant map data. Three of the methods use increasingly detailed boll by position and branch number data, and the fourth is a multiple regression model that was originally developed for interpretive rather than predictive use. Of these, only the method using the most detailed boll retention data appears possibly useful. It appears, however, that to be effective as a predictive tool the method will have to be supplemented with boll size measurements.

Introduction

The practice of final plant mapping involves selecting a sample population of plants from the field and, just prior to harvest, recording detailed structural data from each plant in the population. The population is sampled after the last harvestable boll has matured and before picking. Data sampled in the University of California final plant mapping system include plant height, number of main-stem vegetative branches below the first fruiting branch, number of bolls on vegetative branches, and boll presence or absence by position on each fruiting branch. In the University of California system, which is modeled after that developed by Bourland and Watson (1990), positions are classified according to their proximity to the main stem, with the closest denoted as first position (FP1), the next closest denoted as second position (FP2), and all the rest lumped together and classified as FP3+.

Final plant map data is useful in retrospectively determining the effectiveness of management practices during the season. Several publications describe the use of these data in evaluating crop management practices (e.g., Kerby and Hake, 1996). Another potential use of the data is in providing an estimate of lint yield. The purpose of this paper is to compare four methods of estimating yield based on final plant map data. The first method is to simply relate yield to total bolls per acre. The second is to relate yield to total first position bolls per acre. The third method is based on one used by Landivar and Benedict (1996). This method, which is implemented in J.A. Landivar's plant mapping program PMAP, is based on published data on boll size and contribution of each position to total yield (Jenkins, 1995). The estimate is computed for each position and node by multiplying the fraction of plants with a boll at that location by the number of bolls at that location needed to produce a pound of lint. This product is then summed over all locations and nodes to produce a total estimated yield. The fourth method is based on a multiple regression model of Kerby and Hake (1996). This method was originally developed to summarize the relation between plant map data and yield, not for estimation, and is included for comparison purposes only.

Materials and Methods

Final plant map data (plant height, number of main-stem vegetative nodes below the first fruiting branch, number of bolls on vegetative branches, boll presence or absence by position on each fruiting branch) were recorded for the cultivar Acala Maxxa in each year between 1993 and 1996 at eight locations in the San Joaquin Valley. Plant populations per acre was recorded in all but four of these trials. There were four replications in each year at each location. These locations spanned the Valley and may be considered to provide a representative sample of the growing conditions to be encountered there.

At present, final plant map data in California is recorded and displayed both by fruiting branch number and by main-stem node number (the difference is due to differences between plants in the number of vegetative branches below the first fruiting branch). However, data for years prior to 1996 was often recorded only by fruiting branch, and therefore all our analysis is based on this. Boll retention data is recorded as mean number of bolls per plant by branch number and position (FP1, FP2, and FP3+).

Lint yields were recorded for each trial. Cotton was grown according to University of California management guidelines and maintained as pest-free as possible. The University of California programs CPM (Plant and Kerby., 1995) and CottonPro (Plant and Bernheim, 1996) were used to record data and compute and display statistics. Data were pooled over replications in the analysis. Data were analyzed using Minitab statistical software (Minitab, Inc., State College, PA). Gin turnout was very consistent during this period so that there is a very high correlation between seed yield and lint yield.

Results

Method 1

The simplest method was to simply estimate yield based on total bolls per acre. On average, 320.6 bolls were required to produce a pound of lint (or 153,900 bolls per bale). There is, however, a high degree of variability in this average (the coefficient of variation is cv = 39.7%). The regression relation between yield and total bolls per acre is

$$\text{Yield} = 969 + 0.00102\ \text{Bolls/A},\ r^2 = 0.006,\ \text{NS}.$$

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1446-1450 (1997)
National Cotton Council, Memphis TN

Because of its obvious lack of predictive value, this method was dropped from further consideration.

Method 2

Multiple regression analysis of yield against boll count by position indicated that only total first position bolls, not FP2 or FP3+, correlates significantly with yield. Therefore, in the second method tested we computed a regression relation between total FP1 bolls per acre and yield. One outlier was removed prior to the regression analysis.

Figure 1 shows the linear regression. The outlier is shown as an unfilled square. There is considerable scatter in the data, although not as much as with total bolls. The regression equation for lint yield is

$$\text{Yield} = 299 + 0.00389\ (\text{FP1 Bolls/A}),\ r^2 = 0.37$$

A regression relation with a higher r^2 was actually obtained by relating yield to FP1 bolls per plant (i.e., by neglecting differences in plant population density). The regression relation is

$$\text{Yield} = -437.228+247.214\ (\text{FP1 Bolls/Plant}),\ r^2 = 0.78$$

It should be noted that there was generally little variability in plant population density between these trials. Population density is estimated by counting the number of plants along a fixed row length. We have not attempted to estimate the amount of variability in population density within a field, but it could be considerable.

Method 3

The third method tested is based on one used by Landivar and Benedict (1996). It uses a relationship between boll size and position and fruiting branch number. For each fruiting branch, and for each position on the branch, the contribution to total yield of that position may be estimated as yield = boll size × gin turnout × bolls per plant × plants per acre. The contributions are then summed over positions and branches to obtain the estimate. Landivar and Benedict use boll size vs. position and main-stem node relationships published by Jenkins (1995) for varieties grown in the Mississippi area. Boll size data were not available for Acala Maxxa, but boll size by fruiting branch and position data were recorded in the years 1990-1992 for three Acala varieties, SJ-2, GC-510, and Preema (Kerby et al., 1993). Boll size data from a different cultivar may still be effective for Acala Maxxa if the relative boll sizes are approximately the same between cultivars. In this case, a correction factor could be applied to the values computed for other Acala varieties.

The analysis was carried out for each of the three varieties for which detailed boll size data are available. Only results for Acala GC-510 are shown; those obtained using relationships from the other varieties are almost identical. Figure 2 shows the data and regression curves for boll size as a function of position and fruiting branch number. The equations shown in this figure are:

$$\text{FP1: boll size} = 4.35+0.807\text{FB}-0.0873\text{FB}^2+0.00274\text{FB}^3,\ r^2 = 0.542;$$
$$\text{FP2: boll size} = 3.54 + 0.652\text{FB} - 0.0386\text{FB}^2,\ r^2 = 0.666;$$
$$\text{FP3: boll size} = 4.49 + 0.0759\text{FB},\ r^2 = 0.406.$$

The equation for estimating yield based on bolls size and plant map data is then

$$\text{Estimated Yield} = \sum_{\text{fruiting branches}} \sum_{\text{positions}} (\text{boll size}) \times (\text{gin turnout}) \times (\text{bolls/plant}) \times (\text{plants/acre})$$

Gin turnout over the three-year period had an value of 0.3537.

Estimated yields for the years 1993-1995 computed using this formula followed the same trend as observed yields but were consistently higher, possibly due in part to varietal differences in average boll size. To correct for this, we computed a scale factor as the ratio between mean values of observed and estimated yields. The value of this scale factor is 0.58.

Figure 3 shows the relation between observed and estimated yields for this method. Plant map data was available from four fields whose plant populations were not recorded. To expand the data set, we computed the average plant population over the test to be 44,810 plants per acre, and used this average plant population for these fields, which are shown as unfilled squares in Fig. 3. The solid line in this figure is the observed yield = estimated yield line. The fit between estimated and observed yield, not including those fields whose populations were estimated using the average value, is $R^2 = 0.84$.

Method 4

The fourth method used to estimate yield was a multiple regression model developed by Kerby and Hake (1996). This model was not intended for use as a yield estimator on a field-by-field basis, but rather as an indicator of how quantities measured during final plant mapping relate to yield. Nevertheless, it is useful to include it in the final comparison of the models. The equation is,

$$\text{Yield} = 666 - 91.9\ \text{VB} + 11.33\ \text{PRB5} + 52.34\ \text{FB95}\ (p < 0.0001).$$

Comparison of the Methods, 1996 Data

All of the regression models, except that of method 4, which was developed by Kerby and Hake, were based on 1993-1995 yields. Therefore, the results of 1996 yield trials provide an independent means of testing and validation. Because of its low predictive value on a field-by-field basis, method 1, estimation of yield based on total bolls per acre, was not included in the test.

Method 2, the use of first position bolls per acre, was not effective as an estimator. As shown in Fig. 4, the fit between observed and estimated yield was poor, with an R^2 of 0.13.

Figure 5 shows the relation between observed and estimated yield for method 3. The estimate follows the same trend as the observed, but consistently underestimates the actual yield. The abscissa in Fig. 5 represents the estimated yield computed without the use of the scale factor 0.58. The open diamonds in the figure represent the estimate computed with this scale factor. Evidently, the appropriate scale factor for 1996 was between 0.58 and 1. In fact, the value as computed by comparing average observed vs. estimated values was 0.77. When this scale factor was used, the correlation between estimated and observed yields provided an R^2 of 0.75 (Fig. 6).

Figure 7 shows observed vs estimated yields for the method of Kerby and Hake (1996). The correlation between observed and estimated yield for this method for the 1996 data provided an R^2 value of 0.30

Discussion

Of the four methods, only method 3 appears to show promise for forecasting yield on a field-by-field basis. Although this method followed the correct trend when tested against 1996 data, the appropriate value of the scale factor changed from 0.58 in 1993-1995 to 0.77 in 1996. This could be due to changes in average boll size between the earlier and later yields. This conclusion is supported by the data shown in Fig. 8. This figure plots the average number of bolls per pound of lint against lint yield. These data show that average boll size tends to increase with increasing yield. Average yields in 1996 were 1432 lb/A, compared with 1251 lb/A in 1993-1995.

One may provisionally conclude that average boll size cannot be neglected in attempting to estimate yield on a field by field basis. We have undertaken a program to record boll diameter to determine if this data can be used to increase the accuracy of the predicted yield.

Acknowledgments

This work was supported by the Cotton Incorporated California State Support Committee and by the USDA National Research Initiative Competitive Grants Program, Grant 9403964.

References

Bourland, F. M., and C. E. Watson. 1990. COTMAP, a technique for evaluating structure and yield of cotton plants. *Crop Science*, 30: 224-226.

Jenkins, J. 1995. Useful Tools in Managing Cotton Production: End of Season Plant Maps. Mississippi Agricultural and Forestry Experiment Station, Bulletin 1024.

Kerby, T.A. and K. A. Hake. 1996. Monitoring Cotton's Growth. *In* Cotton Production Manual, S.J. Hake, T.A. Kerby, and K.A. Hake, eds., pp 335-355.

Kerby, T. A., M. Keeley, and M. Watson. 1993. Variation in fiber development as affected by source to sink relationships. *In* Proceedings of the 1993 Beltwide Cotton Conferences, pp. 1248-1251. Memphis, TN: National Cotton Foundation.

Landivar, J. A. and J. H. Benedict. 1996. Monitoring System for the Management of Cotton Growth and Fruiting,. Texas Agricultural Experiment Station Bulletin B02.

Plant, R. E., and L. G. Bernheim. 1996. CottonPro: Software for plant mapping and analysis. *In* Proceedings of the 1996 Beltwide Cotton Conferences, pp. 1198-1200. Memphis, TN: National Cotton Foundation.

Plant, R. E., and T. A. Kerby. 1995. CPM: Software for cotton final plant mapping. Agronomy Journal 87: 1143-1147.

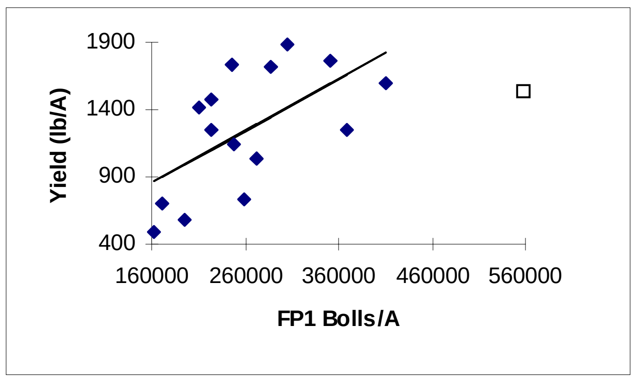

Fig. 1. Plot of regression of lint yield against FP1 bolls per acre. Outlier not used in the analysis is shown a an unfilled square.

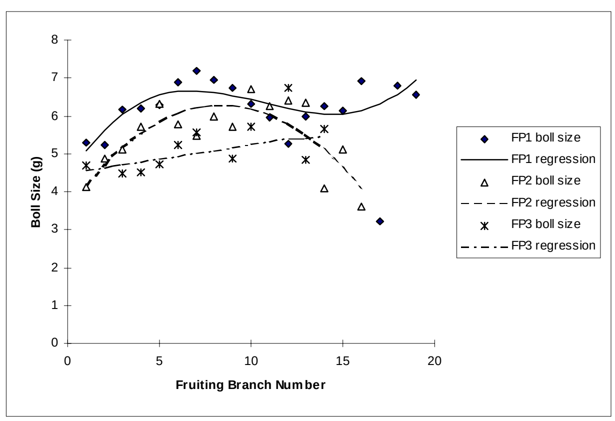

Fig. 2. Boll size (g) as a function of fruiting branch number and position for Acala GC-510 cotton.

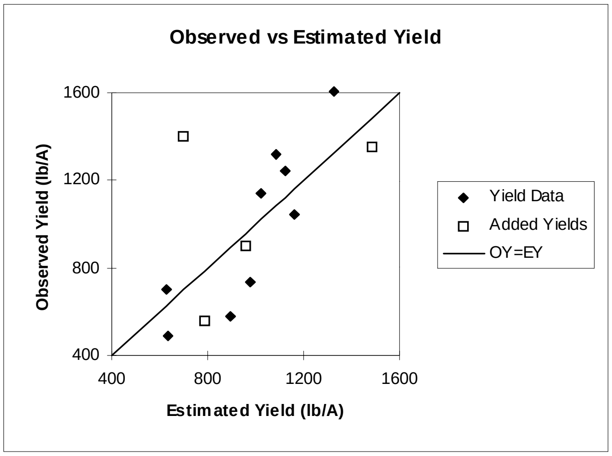

Fig. 3 Observed vs. estimated yields for method 3. The unfilled squares are from fields where plant population was not recorded, but rather was estimated as the average value for the other trials.

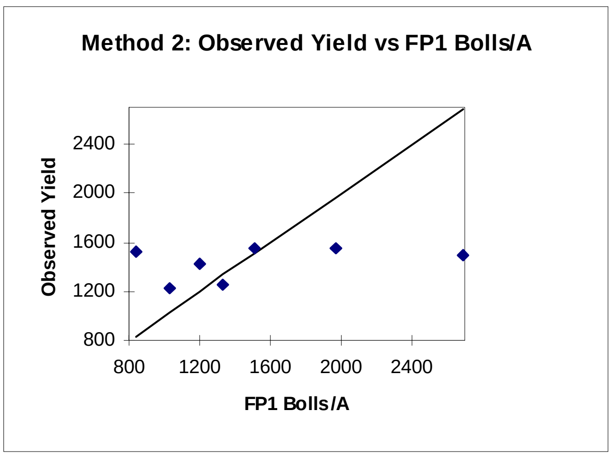

Fig. 4. Observed vs. estimated yield for method 2, 1996 data.

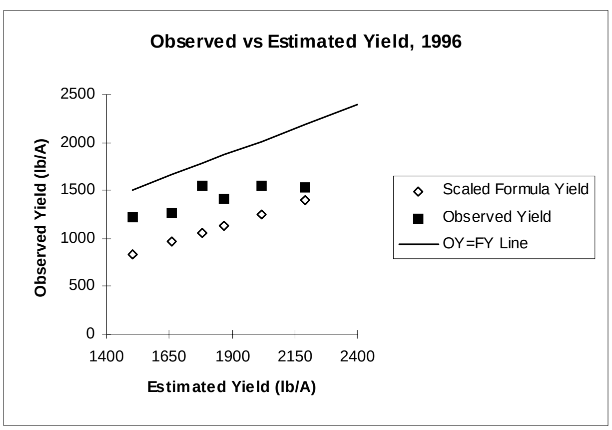

Fig. 5. Observed vs. estimated yield for method 3, 1996 data.

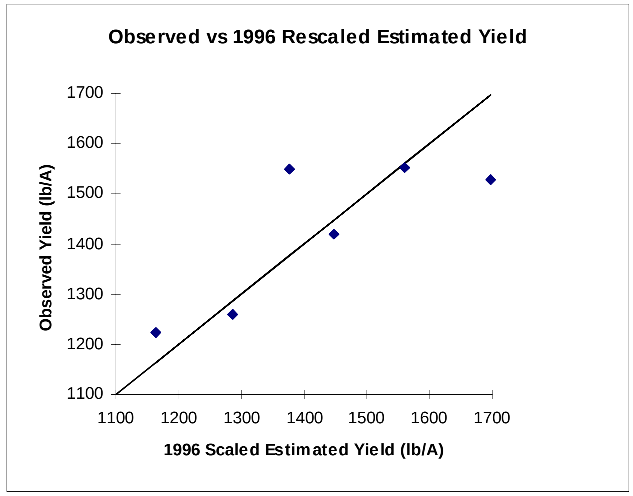

Fig. 6. Observed vs. rescaled estimated 1996 yields, method 3.

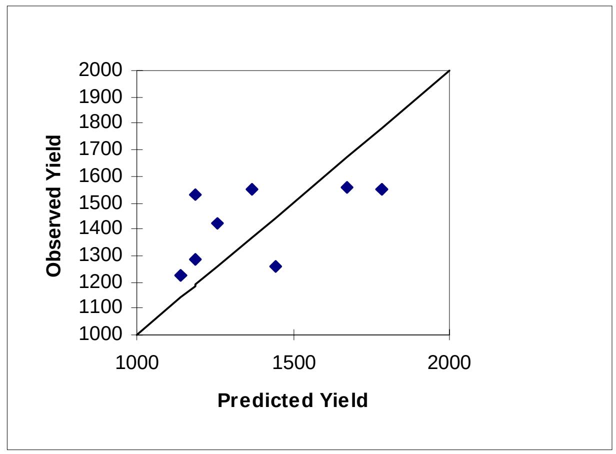

Fig. 7. Observed vs predicted yields for method 4, the multiple regression model of Kerby and Hake, 1996 data.

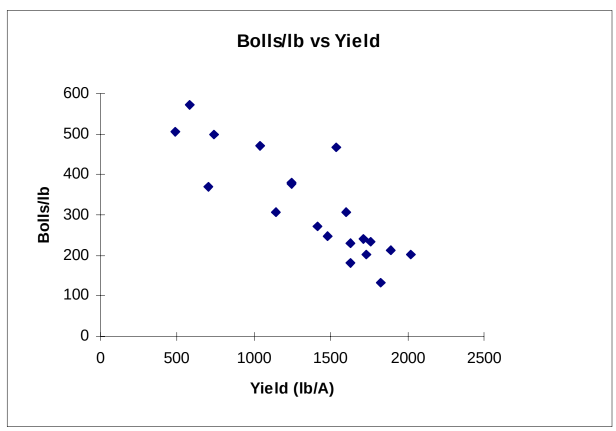

Fig. 8. Average number of bolls per pound of lint on a field by field basis, plotted against lint yield for that field.