INTRA- AND INTER-STATE TRANSFERABILITY OF SOYBEAN VARIETY RESEARCH

Steven A. Henning and B. R. Eddleman

Abstract

An example of agricultural research technology transfer and implications for the fiscal coordination and conduct of agricultural research programs is presented. Uniform Soybean Tests conducted in four Southern States are used to estimate the potential for transferability of soybean variety research among homogeneous sub-areas. The results indicate a high degree of transferability among the sub-areas. Coordinated management of soybean variety research could potentially provide more effective expenditure of soybean breeding research investments. Additionally, the concept or research transferability is not limited to soybeans or soybean variety research. Increased coordination of agricultural research investments by individual states may enhance existing benefits.

Key words: research technology transfer, agricultural research investment, homogeneous sub-areas.

Public investment in agricultural research in the United States is currently directed through a decentralized federal-state system. Responsibilities and research priorities of the state experiment stations are determined primarily by state political boundaries rather than by climatological factors that affect the production of agricultural commodities over broader homogenous geographical production regions. Inter-state coordination of agricultural research among states experiencing similar research problems has resulted primarily from cooperative regional research projects and annual Current Research Information System (CRIS) progress reports.

Previous evaluations of investment in agricultural research have focused primarily on the aggregate investment in agricultural research at the national level or on specific crops at the national level (Sim and Gardner). These studies have been used as evidence that agricultural research is a highly productive investment that should be maintained and expanded beyond current funding levels. Another group of studies (Garren and White, a and b; Otto and Havlicek; White and Havlicek) has attempted to measure the benefits of research investments within a given state, as well as the benefits that accrue to the state from external research investments. Most of these studies utilized state political boundaries in determining the study region.

Other studies of research evaluation have used the geo-climatic regions and sub-regions of the *1957 Yearbook of Agriculture* (USDA) to define the study area. Evenson used these geo-climatic regions to measure the spillover effects of research on agricultural productivity. These regions were differentiated by climate, soils, and agricultural activity. Studies by Papadakis (1961) and Araji also made use of climatic variables (temperature and rainfall) to define homogeneous production regions.

There has been limited analysis of the transferability of agricultural research within homogeneous geographical production regions that cross state political boundaries. Such information would aid in improving fiscal coordination and conduct of research programs among the various State Agricultural Experiment Stations (SAES), and among the SAES and the United States Department of Agriculture (USDA) research agencies. Information is needed that would improve interstate fiscal coordination and/or the actual conduct of research among multi-state areas.

Steven A. Henning is an Assistant Professor, Department of Agricultural Economics and Agribusiness, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center and B. R. Eddleman is a Professor, Department of Agricultural Economics, Mississippi State University.

This article is a contribution to the IR-6 project, National and Regional Research Planning and Analysis, of the State Agricultural Experiment Stations.

Such information would identify opportunities for intra-and inter-state transferability of agricultural research technology.

The objectives of this paper are to: (1) determine homogeneous sub-areas in a multistate study region based on the physiological requirements of soybeans; (2) evaluate the transferability of soybean variety research within and among the homogeneous sub-areas; and (3) present implications for the fiscal coordination and conduct of agricultural research programs. The study utilizes cluster analysis based on climate, soil, daylength, and latitude to determine homogeneous sub-areas. An analysis of variance of Uniform Soybean Tests conducted in four southern states is presented to determine the potential for the transferability of soybean variety research from one homogeneous sub-area to other homogeneous sub-areas within the study region.

DETERMINATION OF HOMOGENEOUS SUB-AREAS

The initial effort was to determine homogeneous sub-areas. The study region was comprised of 264 counties, including all of the counties in Arkansas, Louisiana, and Mississippi, plus most of the counties in Alabama. Counties in the northeast corner of Alabama were excluded from the study region because of non-homogeneity of soil types and terrain. States included in the study shared four general characteristics: (1) soybeans were a major cash crop; (2) similarity of climate; (3) similarity of major soil associations; and (4) similarity of daylength and latitude factors.

These characteristics were the basis for defining homogeneous sub-areas within the study region by means of a k-means clustering algorithm (Hartingan). Each county in the study region represented one observation in the clustering algorithm. K-means clustering partitioned the observation into the cluster whose center (the mean of observations in the cluster) was nearest to the observation.

Euclidean distance was used to measure the distance between each observation and the center of each cluster. Data used to compute cluster center and Euclidean distances were standardized by dividing each variable by its standard deviation. The square of the Euclidean distance for observation i and cluster j was:

$$(1)\ d_{ij}^2 = 1/p\ (x_i - c_j)\ M^{-1}\ (x_i - c_j)',$$

where:

x_i = vector of observations $x_{i1}, x_{i2}, \ldots, x_{ip}$;

c_j = vector of the center of clusters $c_{j1}, c_{j2}, \ldots, c_{jp}$;

M = a diagonal matrix of the variances of the standardized variables;

p = the number of clusters; and

d_{ij} = Euclidean distance of observation i and cluster j.

The cluster analysis was based on data for the years 1961 to 1980. This represented the period of growth in the production of soybeans that led to its current status as a major cash crop in the study region. The long length of the period also offset any bias created by annual deviations from the long-term means of weather variables included in the analysis.

Variables in the cluster algorithm represented climate, daylength, and soils. Climatic data were collected for each month of the soybean production season (April through November) from weather stations located in each county in the study region (National Oceanic and Atmospheric Administration (a, b, c, and d)). Counties lacking adequate weather station data were assigned proxy stations from neighboring counties on the same latitude.

Three climatic variables included in the cluster algorithm were average monthly maximum temperature, average monthly minimum temperature, and monthly total precipitation. The 20-year mean of each of the 8 months of the soybean production season provided the observation value for these variables and accounted for 24 of the 42 variables in the clustering algorithm. The long-term mean of each climatic variable was assumed to be representative of the normal temperature and precipitation expected in each county.

Two other variables in the cluster algorithm utilized the 20-year means of temperature and precipitation to calculate a monthly humidity index and a monthly measure of excess rainfall for each county. Both variables were proxy measures for available soil moisture during the month. The humidity index indicated the degree to which monthly total precipitation exceeded potential evapotranspiration.[1] The difference between total precipitation and potential evapotranspiration for the month was also used as a proxy measure of soil moisture. The relative value of monthly excess rainfall indicated whether excess or deficit levels of soil moisture existed.

The daylength variable was related to the physiological needs and adaptability of soybeans. Soybeans adapted to the study region require at least 14 and 1/2 hours of daylength at planting to produce near their maximum potential (Hartwig and Jordan). The length of the dark period is the controlling factor in eliciting photoperiodic responses. Soybean variety research is organized around this known response to daylength. The study region was within the boundaries of 29° latitude along the Gulf Coast and 37° latitude in the northernmost portion of the region. The daylength variable was measured by ranking one degree changes in latitude from south to north in the study region. Each county was assigned the rank of the latitude which described the majority of its land area.

The final variable in the cluster algorithm represented the diversity of soils in the study region. Major Land Resource Areas (MLRA's) were used to describe the different soils. Each county was assigned to a MLRA based on the estimated percentage of land area in the MLRA. If the land area of a MLRA was 25 percent or more, it was defined as a dominant MLRA. A county could have been described by a single dominant MLRA or by a combination of dominant MLRA's. A total of 37 single or combined dominant MLRA's were identified and ranked. The rankings were then used to describe the soils in each county.

RESULTS FROM THE CLUSTER ANALYSIS

Two criteria guided the formation of homogeneous clusters of soybean production sub-areas. First, the total number of homogeneous sub-areas was minimized to eliminate sub-areas containing only one or two counties. Secondly, the homogeneous sub-areas were required to be contiguous so as to minimize the number of outlying counties in each sub-area. This criterion eliminated one or two county sub-areas that were widely separated from the body of remaining counties in the sub-area.

The clustering was conducted for cluster sets ranging from seven to fifteen in number. Analysis of these cluster sets indicated that the number of outlying counties decreased as cluster sets increased from seven to eleven. However, cluster sets greater than eleven lost contiguity as the number of outlying counties increased with the number of clusters. Sub-areas of two to four counties became more frequent.

The solution for a set of eleven clusters included one cluster containing only one county and eleven counties that were geographically separated from their assigned clusters. Following the previously stated criteria, the solution was modified to eliminate single county clusters and to form contiguous sub-areas. Outlying counties were reassigned based on two additional criteria. One criterion was that the soils of the county being moved be compatible with the soils of the new cluster assignment. The second criterion required that the latitude of the county being moved correspond to the latitude of the new

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[1] Evapotranspiration was defined as the sum of water consumed by plant transpiration and soil evaporation. Papadakis (1966) used this measure to classify climate as humid, intermediate, or dry. The humidity index was defined as:

$$HI = P/E$$

where:

HI = monthly humidity index;
P = monthly total precipitation; and
E = monthly total potential evapotranspiration.

Data on monthly precipitation were available from the weather stations in each county. Monthly potential evapotranspiration was measured as:

$$E = e_{max} - (e_{min} - 3.6),$$

where:

e_{max} = inches of saturation vapor pressure corresponding to average monthly maximum temperature; and

e_{min} = inches of saturation vapor pressure corresponding to the average monthly minimum temperature. The constant value 3.6 is the normal difference between the average minimum temperature and the dew point.

cluster assignment. These criteria preserved the original impact of the daylength and soil variables used in the clustering algorithm.

This modified solution identified ten homogeneous soybean production sub-areas, Figure 1. The grouping of counties into subareas from north to south closely approximated the maturity group zones used in soybean variety research. The grouping of counties from east to west seemed to have been heavily influenced by soils, often following the pattern of Major Land Resource Areas.

Seven of the ten sub-areas crossed state political boundaries. Three of those seven sub-areas included counties from three of the four states in the study. The three subareas remaining completely within state political boundaries had MLRA characteristics that distinguished them from surrounding subareas. The number of counties in a subarea ranged from as few as 13 to as many as 42.

TRANSFERABILITY OF SOYBEAN VARIETY RESEARCH

Maturity groups are used in soybean variety research to classify varieties by their response to daylength (i.e., length to maturity). Soybean varieties are classified into 10 maturity groups, 00 to 8. Varieties in Maturity Group 00 are adapted to southern Canada and the northernmost areas of the United States and are the earliest to maturity. Maturity Group 8 varieties are adapted to the Gulf Coast area of the United States and have the longest length to maturity. Generally, only Maturity Groups 5 through 8 are adapted to the study region under consideration.

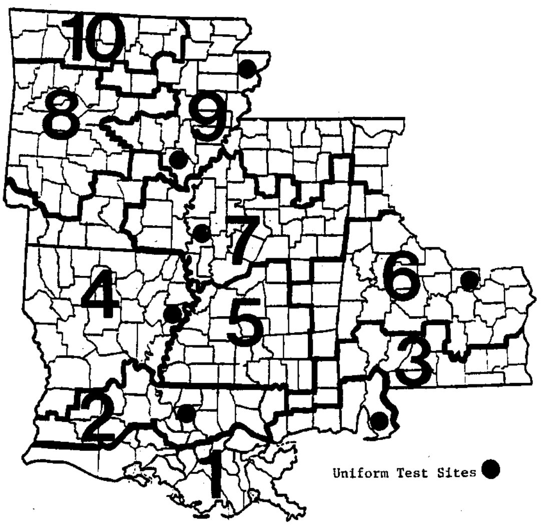

Figure 1. Homogeneous Soybean Production Subareas of the Study Region; Alabama, Arkansas, Louisiana, and Mississippi.

TABLE 1. REPRESENTATIVE UNIFORM SOYBEAN TEST SITES AND MATURITY GROUPS FOR EACH HOMOGENEOUS SOYBEAN PRODUCTION SUBAREA; ALABAMA, ARKANSAS, LOUISIANA, AND MISSISSIPPI

Homogeneous subarea	Uniform test site	Maturity group
1	Fairhope, Alabama	8
2	Baton Rouge, Louisiana	8
3	Fairhope, Alabama[a]	8
4	St. Joseph, Louisiana[a]	7
5	St. Joseph, Louisiana[a]	7
6	Tallassee, Alabama	7
7	Stoneville, Mississippi A[b]	7
8	Stuttgart, Arkansas[a]	6
9	Stuttgart, Arkansas	6
10	Keiser, Arkansas B[ab]	5

[a] Test site is located outside the homogeneous subarea.
[b] The A or B designation indicates only one of several test sites at this location.

Once the homogeneous subareas were defined, Uniform Soybean Test sites were identified within each subarea. A Uniform Soybean Test site was assigned to represent each subarea based on the maturity group that best described the subarea and the proximity of the test site to the subarea. This effort was limited somewhat because only a few test sites had complete data. Subareas 3, 5, 8, and 10 had no Uniform Soybean Test sites within their boundaries. These subareas were assigned proxy sites as shown in Table 1.

Experimental variety tests had been conducted for one or more of the maturity groups included in this study at each site. In most cases, several of the test sites were used in conducting variety tests for cultivars in the same maturity group. These data were used to determine the transferability of experimental soybean variety research by testing for significant effects on experimental soybean yields due to the variety used and the locations of the test.

The hypotheses tested were that there was no significant effects on yields of experimental varieties due to: (1) varietal differences; (2) the location of Uniform Soybean Test sites among the homogeneous sub-areas included in the test; and (3) the interaction of varieties and the location of the Uniform Soybean Test sites among the homogeneous subareas included in the test.

An analysis of variance was completed for each maturity group included in the study area (Maturity Groups 5, 6, 7, and 8). Data needs for conducting an analysis of variance were annual yields of experimental varieties at Uniform Soybean Test sites included in the

TABLE 2. EXPERIMENTAL VARIETIES AND UNIFORM SOYBEAN TEST SITES USED IN DETERMINING THE TRANSFERABILITY OF SOYBEAN VARIETY RESEARCH, 1975-1978

Experimental variety (years)	Location (subarea no.)
Maturity Group 5:	
Forrest (1976-78)	Keiser, Arkansas B (subarea 10)
V72-580 1976-78)	Stuttgart, Arkansas (subarea 8, 9)
N73-40 (1976-78)	Stoneville, Mississippi A (subarea 7)
	St. Joseph, Louisiana (subarea 4, 5)
Maturity Group 6:	
N72-137 (1976-78)	Keiser, Arkansas B (subarea 10)
N72-3058 (1976-78)	Stuttgart, Arkansas (subarea 8, 9)
N72-3148 (1976-78)	Stoneville, Mississippi A (subarea 7)
	St. Joseph, Louisiana (subarea 4, 5)
	Fairhope, Alabama (subarea 1, 3)
	Baton Rouge, Louisiana (subarea 2)
Maturity Group 7:	
Ransom (1976-78)	Stuttgart, Arkansas (subarea 8, 9)
Ga Soy 17 (1976-78)	Stoneville, Mississippi A (subarea 7)
N72-3189 (1976-78)	Tallassee, Alabama (subarea 1, 3)
	St. Joseph, Louisiana (subarea 4, 5)
	Fairhope, Alabama (subarea 1, 3)
	Baton Rouge, Louisiana (subarea 2)
Maturity Group 8:	
Cobb (1975-78)	Tallassee, Alabama (subarea 6)
Coker 338 (1975-78)	Fairhope, Alabama (subarea 1, 3)
F70-2060 (1975-78)	Baton Rouge, Louisiana (subarea 2)
Ts73-16 (1975-78)	

study (Hartwig). Only a limited number of experimental varieties remained in the Uniform Soybean Test for 3 years or longer. Three criteria were used to select the experimental varieties included in the analysis of variance of each maturity group. They were: (1) to use the most recent yields available; (2) to maximize the number of experimental varieties and the total number of observations; and (3) to require a minimum of 3 years of annual yield data for each variety selected at each location.

All of the subareas were not represented in each analysis of variance because the representative test site was not included in all maturity group variety tests. The experimental varieties and Uniform Soybean Test sites included in each maturity group are given in Table 2.

RESULTS

Analysis of variance for Maturity Groups 5, 6, 7, and 8 are shown in Table 3. The conclusions of the hypothesis testing were the same for all maturity groups tested. Calculated F ratios of the first and third hypotheses were not significant at the 5 percent level for any of the maturity groups tested. The hypotheses that there was no significant variety effect on experimental yields could not be rejected. In addition, the hypothesis that there was no significant difference in yields due to the interaction of experimental varieties and the location of Uniform Soybean Test sites among the homogeneous subareas included in the test could not be rejected for any of the maturity groups in the study.

TABLE 3. ANALYSIS OF VARIANCE OF DIFFERENCES IN EXPERIMENTAL SOYBEAN YIELDS AMONG HOMOGENEOUS PRODUCTION SUBAREAS DUE TO VARIETY AND LOCATION, BY MATURITY GROUP, 1975-78

Item	Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-ratio
Maturity Group 5:	Total	35	1,970.23		
	Between subclasses	11	754.77		
	Between varieties	2	168.05	84.03	1.66
	Between locations	3	530.47	176.82	3.49[a]
	Interaction	6	56.25	9.37	0.19
	Within subclasses	24	1,215.46	50.64	
Maturity Group 6:	Total	53	4,072.30		
	Between subclasses	17	1,880.12		
	Between varieties	2	31.64	15.82	0.26
	Between locations	5	1,690.86	338.17	5.55[b]
	Interaction	10	157.62	15.76	0.26
	Within subclasses	36	2,192.18	60.89	
Maturity Group 7:	Total	53	4,026.97		
	Between subclasses	17	1,551.69		
	Between varieties	2	83.80	41.90	0.61
	Between locations	5	1,342.70	268.54	3.91[b]
	Interaction	10	125.19	12.52	0.18
	Within subclasses	36	2,475.28	68.76	
Maturity Group 8:	Total	47	3,993.32		
	Between subclasses	11	1,309.29		
	Between varieties	3	11.08	3.69	0.05
	Between locations	2	1,127.42	563.71	7.56
	Interaction	6	170.79	28.46	0.38
	Within subclasses	36	2,684.03	74.56	

[a] Significant at the 5 percent level.
[b] Significant at the one percent level.

Differences in yields due to the location of the Uniform Soybean Test sites among the homogeneous sub-areas included in the test were significant at the 5 percent level in Maturity Group 5 and at the 1 percent level in Maturity Groups 6, 7, and 8. The hypothesis that there was no significant difference in yields due to locational effects was, therefore, rejected.

Results from the hypothesis testing indicated that variety research within specified maturity groups was transferable from one homogeneous subarea to another. Experimental varieties did not significantly affect yields among the homogeneous subareas included for each maturity group. Nor did the interaction of experimental varieties and location have any significant effect on yield. Any significant variation in the yields of experimental varieties included in this analysis between subareas for the same maturity group was due to the effect of location on yields. Locational effect accounted for factors other than variety that influenced yields. Those factors were primarily the influence of soils and weather. Standard management practices were applied at each test site for all varieties and were therefore not an influence on variation in yields.

IMPLICATIONS

Results of this study indicate a high degree of transferability for soybean variety research among the delineated homogeneous subareas. This transferability of soybean variety research is a result of breeding programs to develop and maintain wide adaptability of genotype across the southern region. Two important implications are raised with regard to these breeding research programs. First, the current regional research management program, which concentrates soybean variety research at a small number of strategically located test sites, has resulted in varieties adaptable to large acreages under production across the South. The emphasis of this program is to consistently maintain selected test sites rather than broader diversification of test sites across the study region. In this regard the spillover effects from one breeding site to producers in other states are quite large. Secondly, yields are possibly being foregone because soybean variety development research is not directed toward the specific micro-climates of the various homogeneous subareas. Should the current research program be expanded to include adaptation of soybean varieties, developed at central sites, to each homogeneous subarea, then yields might be substantially improved in the various subareas. Such a program would need to coordinate research efforts at additional test sites within each homogeneous sub-area. For either case, the coordinated mangement of soybean variety research among the states included in this study could potentially provide more effective expenditure of soybean breeding research investments.

Fiscal coordination and conduct of research among the SAES in the study has been limited primarily to cooperative regional research projects and CRIS progress reports. The current study indicates that further coordination of soybean variety development research may enhance existing benefits. The concept of research transferability is not limited, however, to soybeans or soybean variety research. Other crops in the study region may benefit from close analysis of potential research transferability. Research in cultural practices, pest management, and double-cropping systems are also likely candidates for transferability. Application of the regional management concept in these and other research areas could provide the consistent testing procedures and resulting data necessary to evaluate the potential for transferability of such research technology.

Increased regional coordination of the agricultural research investments of individual states should be encouraged as a means of maintaining the high rates of return from agricultural research currently being experienced. The resulting spillover benefits of more efficient use of limited research funds may be considerable. As federal and state funding becomes more restricted, tangible proof of the effort and success of agricultural research will become extremely important.

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