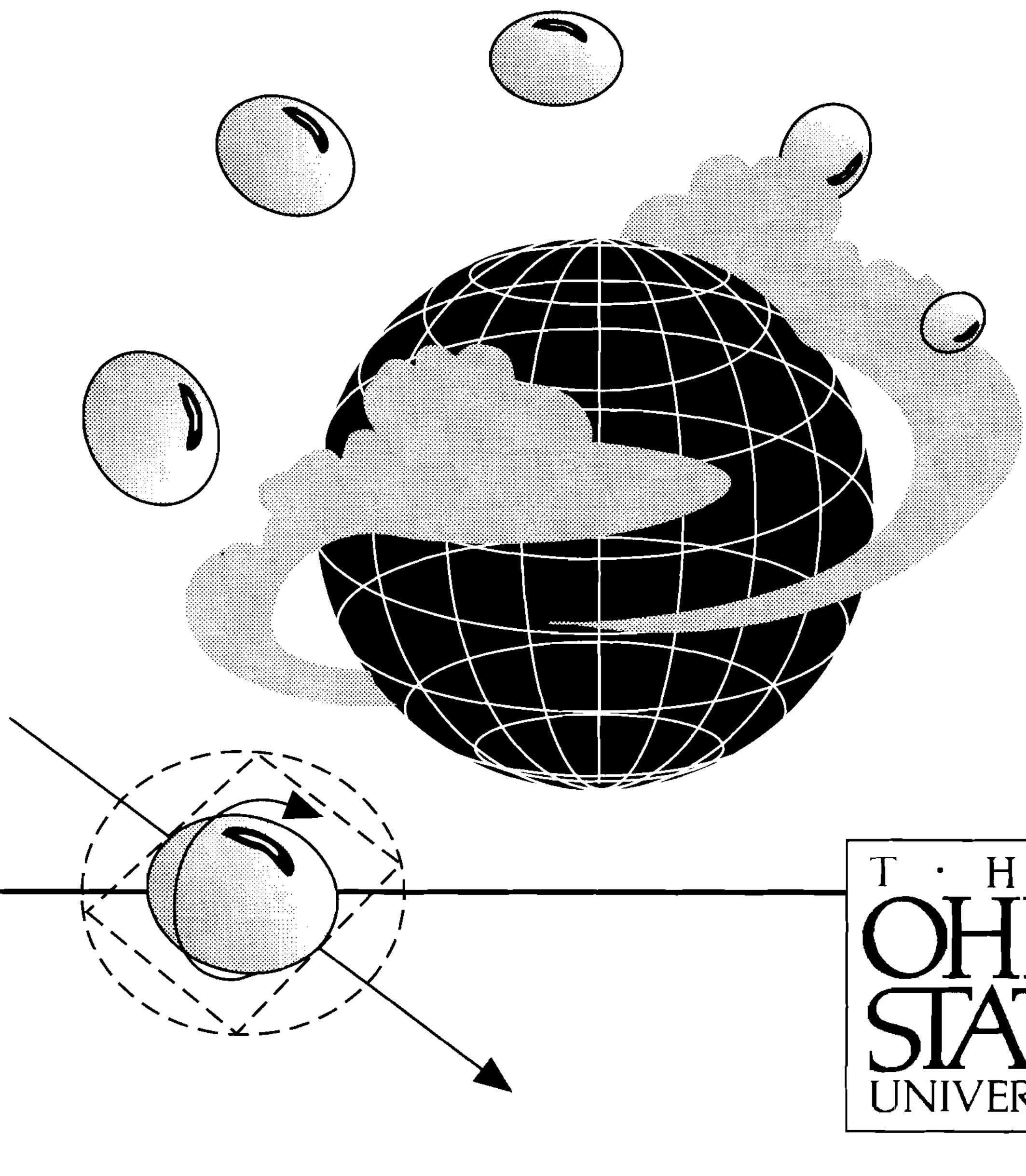
Agronomy Technical Report 9301

Soybean Composition as Affected by Variety and Weather, and its Importance in the World Market



THE OHIO STATE UNIVERSITY

The Ohio Soybean Council invested producer check-off funds to support the writing, reproduction, and distribution of this bulletin. Information contained herein describes the importance of grain quality in holding current markets and securing new ones. The data can help Ohio's soybean farmers select varieties with increased oil and protein content, making Ohio soybeans more competitive in the world market and of premium value.

OHIO SOYBEAN COUNCIL

PRINTED WITH SOY INK
TRADEMARK OF THE AMERICAN SOYBEAN ASSOCIATION TM

All educational programs and activities conducted by Ohio State University Extension are available to all potential clientele on a nondiscriminatory basis without regard to race, color, creed, religion, sexual orientation, national origin, sex, age, handicap or Vietnam-era veteran status.

12/92—10M

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Keith L. Smith, Director, Ohio State University Extension.

Soybean Composition as Affected by Variety and Weather, and its Importance in the World Market

by **Dr. Jim Beuerlein**, Department of Agronomy, Ohio State University

Soybeans are grown for their oil and protein content which is normally around 20% and 40%, respectively, on a dry weight basis. The oil is used in hundreds of food products such as cooking oils and salad dressings, and in many industrial products and processes. Soybean protein is used extensively as a human food and a livestock protein supplement. In the U.S., soybean oil and protein are the more important products produced from soybeans, but export beans are sold primarily for their protein since the world has a number of alternative oils.

More soybeans are grown in the United States than anywhere else in the world. Currently, over 440,000 farmers produce almost 2,000,000,000 bushels each year. Although its a relatively new crop in the United States, the Chinese grew soybeans over 5,000 years ago. In the early 1800's clipper ships brought soybeans to the U.S. from China as an inexpensive ballast in their holds. Upon arrival the soybeans were dumped to make room for cargo. U.S. farmers first grew soybeans in 1829 for soy sauce, and by the late 1800's a significant number of farmers were growing soybeans for livestock forage. In 1930 U.S. soybean production stood at 9,000,000 bushels, but by 1940 production increased to 78,000,000 bushels harvested from about 5,000,000 acres (16 bu/ac). In the early 50's soybean meal became available as a low-cost, high protein ingredient, and triggered an explosion in U.S. livestock and poultry production. In 1959 the soybean industry and the American Soybean Association started looking for ways to expand the market for soybeans by promoting U.S. soybeans in Japan. Today, 29 states grow soybeans and market almost half the production to other countries. Japan and Europe are our largest customers, but markets in many other countries are being developed by the American Soybean Association and the United Soybean Board.

Over the years, acreage and yield have both increased, but have fluctuated due to weather, market demand, prices, and government programs. Figure 1 shows how yield and acreage have changed in the United States since 1900 and in Ohio since 1930.

Figure 1a: Ohio soybean acreage and yield for 1930 - 1990.

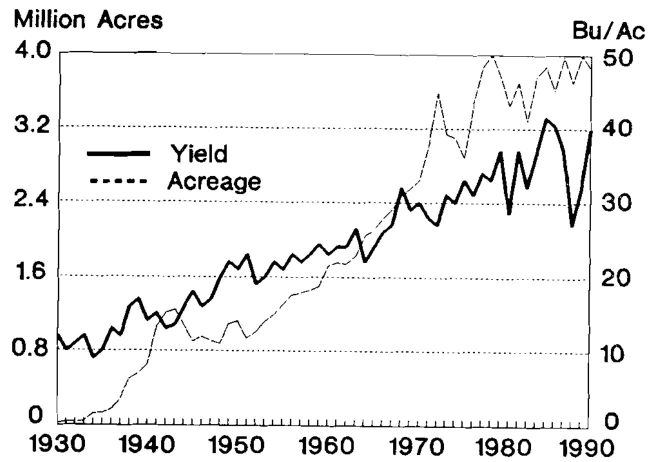
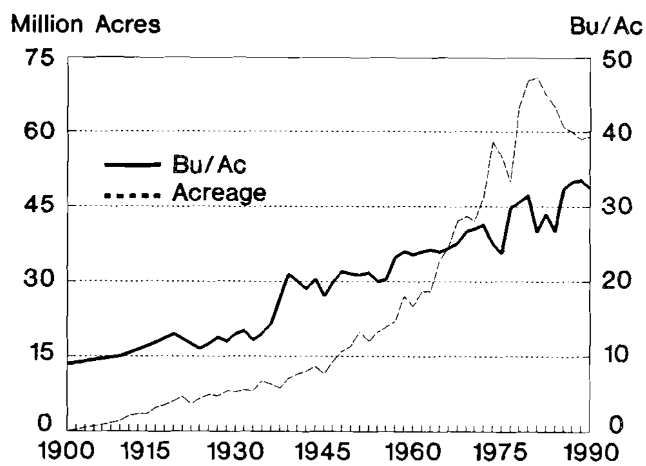


Figure 1b: U.S. soybean acreage and yield for 1900 - 1990.



The Problem

Prior to the 1980's the U.S. was the primary supplier of soybean, soy oil, and soy protein to the world market. Since that time Brazil, Argentina and other South American countries have greatly increased production and are now very strong competitors for that market. Between 1981 and 1990 the United States' share of the world soybean market decreased from nearly 81 percent to less than 60 percent. That same period also saw the U.S. share of world meal and oil markets decrease from 58 and 39 percent to just 19 and 18 percent, respectively. Many soybean producers think these market losses are due in part to the higher foreign matter (FM) percentages in U.S. soybeans. While FM levels of U.S. soybeans are well within grade specifications, they average almost a percentage point higher than South American soybeans. A second reason given for lost market share is that South American soybeans are thought to have higher average oil and protein contents than U.S. beans. If this is true, buyers of soybeans on the world market receive more oil and protein and less FM per unit of currency when purchasing South American soybeans. For these reasons, whether real or perceived, the U.S. has become a "last resort" soybean supplier.

According to the European Oil Processors Association, South America exports a better quality soybean than the U.S. They say South American soybeans are usually a little higher in oil and protein, but most importantly, they are sold on a 1% FM basis, while US beans are sold on a 2% FM basis. One percent less FM equates to 0.4% more protein and 0.2% more oil worth about $0.12 per bushel or $120,000.00 for each 1,000,000 bushel of beans sold. Coupled with high internal subsidies for European grown oil seeds the result has been that our share of the European market decreased from 73% in 1986 to only 48% in 1990. Since 1986 our share of the Japanese market has also decreased from 96% to just over 70%. The reduced share of the Japanese market alone costs the American soybean industry about $200 million in 1990/1991.

A Possible Solution

In an effort to dike the loss of market share, the Federal Grain Inspection Service (FGIS) has proposed cutting the FM tolerance for No. 1 soybeans from 1% to 1/2 percent and No. 2 soybeans from 2% to 1%, which are the same limits used in Brazil and Argentina. The FGIS has also initiated a policy of providing oil and protein content data to U.S. customers on request. It is further anticipated that prior to the year 2000, they will propose the addition of oil and protein contents to standards for the various grades of U.S. soybeans. In effect, this process hopes to ensure customers a competitive product value (oil and protein) per unit currency when purchasing U.S. soybeans.

In a free market, we cannot expect change without sufficient reward in the marketplace. Quality problems are the result of actions in all parts of the industry, from plant breeders to producers, processors and exporters. We must remember that once the soybeans leave the farm or the elevator, they are no longer under the control of the one who produced, sold or certified the quality. Soybean quality will not change until there is an economic incentive to do so for those controlling quality. Because grades do not include oil and protein content, producers have no incentive to check the oil and protein content of the varieties they grow. Yield potential and characteristics other than oil and protein content are the criteria farmers use to select varieties. Changing grade standards and pricing practices may be one way to eliminate the incentive for elevators to blend low and high quality beans. But a more effective inducement is to reward those who produce quality that is of greater value. Soybeans with a combined oil and protein content of 62 percent instead of 58 percent would be one example. Plant breeders have repeatedly stated that large changes can by made in the physical and chemical properties of soybeans. However, if producers are paid for bushels, they will select varieties for yield and companies will not market seed on the basis of chemical composition.

Soybean Oil and Protein Content

Any discussion of soybean quality raises several questions, such as: What factors determine the oil and protein content of soybeans? Can the contents be changed, and how can we change them? In an effort to answer these questions, the Ohio Soybean Association and the Ohio Soybean Council, working with Dr. Jim Beuerlein at Ohio State University, conducted a 4-year study starting in 1988 by collecting grain samples of each variety harvested from the Ohio Soybean Variety Performance Trials. Following plot harvest, samples from multiple locations were cleaned and analyzed for oil and protein content using the "Near Infrared Transmittance" technology. Over a period of time, this data has provided information about environmental and varietal effects on oil and protein content. Table 1 identifies the sites; number of varieties tested; maximum, mean, and minimum oil and protein content; and yield for each of the nine test sites over four years.

In order to determine the effect of the test site on oil and protein content, the database was sorted to isolate those varieties appearing at all nine test sites. Seventeen varieties meeting that criteria were subjected to an analysis of variance of percent oil, percent protein, yield, and % oil + % protein content (% OP). The test sites and varieties both had statistically significant effects on oil and protein content, yield, and the % OP content. As seen in Table 2, the mean oil content of the 17 varieties ranged from a low of 19.8% to a high of 22.9% when the moisture content was adjusted to 0.0%.

Percent protein ranged from a low of 38.5% to a high of 41.2%, while yield ranged from 32.6 to 54.5 bu/ac and % OP varied from 59.7 to 62.8. The production site had much more effect on yield than on composition. Thus, oil and protein content alone and in combination were more stable across environments than yield. This fact should provide some comfort to grain processors relative to the consistency of product they can expect as weather changes from year to year.

The % oil, % protein, yield and % OP for each of 17 varieties averaged across location can be seen in Table 3 which is arranged from high to low values of % OP. Values of % oil ranged from 20.3 to 21.8 while protein content ranged from 38.5% to 42.2%. Yield ranged from 39.8 to 47.7 bu/ac and the % OP ranged from 59.6 to 62.5. The range in % oil as affected by variety compared to the lowest oil content was 7.4%. Similar values for % protein, yield (bu/ac) and % OP were 9.6%, 19.8%, and 4.8%, respectively. Therefore, variety differences were greatest for yield and least for % OP, with % oil and % protein being intermediate. This means that plant breeders would be able to increase yield more easily than oil and protein content.

The data in Tables 2 and 3 clearly indicate that soybean oil and protein content is a function of both location of production (soil and weather) and variety. While a producer has complete control over the varieties he produces, there is little control of the production site and the weather associated with it. Table 4 shows the variation in several weather factors for the nine test sites and Figure 2 shows how the oil and protein content of 17 varieties changed with site. This chart shows no clear pattern of change in that sometimes oil and protein contents changed in the same direction and at other times in opposite directions.

Because 1988 and 1991 were droughty at some locations, we sorted the data by location to eliminate soil type and fertility differences so that the remaining differences would be due primarily to weather. Figure 3 shows the data for 1988-1991 at the Northwest branch of OARDC. The weather in 1988 and 1991 was hotter and drier than normal for that location while 1989 and 1990 were somewhat normal. Comparing 1988 and 1989 we saw oil content decrease and protein content increase as we move from 1988 to 1989. The opposite happened between 1990 and 1991 when the weather changed from normal to hot and dry. At the Western branch OARDC the weather shifts were not as great and the oil and protein content tended to move together. Figure 4 was produced by sorting the data by location mean yield and plotting yield vs. oil and protein content. In that chart both oil and protein content remained relatively constant while yield increased 40 percent, which indicated that oil and protein do not always change as yield changes.

Next we tried correlating various weather components (rainfall, temperature, etc.) to yield, oil and protein content.

Figure 5 shows the correlation coefficients we obtained. Yield was negatively correlated with mean air temperature, solar energy, and soil temperature and positively correlated with rainfall. Weather factors had opposite effects on oil and protein content. As solar radiation, soil and air temperature increased, so did the oil content. The % OP reacted similarly to % protein. A graphic presentation of these responses is seen in Figures 6-8.

Since both oil and protein contents determine the value of soybeans, we also plotted the % OP against yield to produce Figure 9 and observed that oil and protein combined tended to increase as yield increased. Splitting out the data by location and plotting yield vs. % OP did not prove enlightening beyond what can be observed in Figure 9.

Next it seemed appropriate to investigate the relationships of variety vs. yield, and variety vs. % OP. The data was sorted by % protein and then plotted in Figure 10. Both oil and protein change with variety, sometimes increasing together, but in opposite directions at other times. The correlation coefficient for yield and % oil was 0.09, while for % protein it was -0.20. This means that as yield increased due to variety, the % oil increased, and the protein content dropped. The correlation between % oil and % protein was -.045 which implies that as % protein increases the oil content decreases.

Table 1. Site; number of varieties tested; maximum, mean, minimum oil and protein content (0.0% dry wt. basis); and mean yield (bu/ac) of all varieties at each test site.

Test Site*	Number of Varieties	% Oil Max.	% Oil Mean	% Oil Min.	% Protein Max.	% Protein Mean	% Protein Min.	Mean Yield (bu/ac)
1	154	23.7	20.9	19.2	42.5	40.2	36.3	33.6
2	168	23.9	21.0	18.1	42.6	39.5	35.7	36.6
3	146	24.3	22.2	20.3	41.9	38.6	35.9	32.8
4	227	22.8	19.8	17.8	42.9	39.9	37.1	50.7
5	227	21.6	20.4	17.8	44.9	38.3	41.0	54.7
6	207	23.7	21.6	19.1	44.8	41.1	37.4	54.4
7	207	22.9	20.9	18.7	45.3	40.7	32.4	50.7
8	188	23.8	21.3	19.7	43.3	40.9	38.2	48.6
9	188	24.3	22.5	20.9	41.7	38.1	35.0	35.3

*1 = 1988 Western Branch OARDC
2 = 1988 Northwest Branch OARDC
3 = 1988 Farm Focus
4 = 1989 Western Branch OARDC
5 = 1989 Northwest Branch OARDC
6 = 1990 Western Branch OARDC
7 = 1990 Northwest Branch OARDC
8 = 1991 Western Branch OARDC
9 = 1991 Northwest Branch OARDC

Table 2. Mean % oil, % protein, yield and % OP of 17 soybean varieties for each of nine test sites.

Site	% Oil*	% Protein*	Yield (bu/ac)**	% OP*
1	21.0	40.2	34.1	61.2
2	20.7	39.9	36.5	60.5
3	22.9	39.0	32.6	60.9
4	19.8	39.9	51.9	59.7
5	20.5	40.9	54.4	61.4
6	21.8	41.0	54.5	62.8
7	20.8	41.2	50.8	62.8
8	21.3	41.0	47.5	62.3
9	22.5	38.5	34.7	61.0
Mean	21.1	40.2	44.1	61.3
LSD .05	0.35	0.56	2.74	0.49

*measured on the basis of zero percent moisture
**yield of 13% moisture

These relationships can be seen in both Figures 10 and 11. When we plotted yield against % OP, we observe that both low and high yielding varieties can have either low or high concentrations of oil and protein. If soybeans are eventually priced for their oil and protein content, then producers will be able to generate more income with relatively high yielding varieties having high levels of oil and protein than with higher yielding varieties that have low oil and protein contents.

The above data suggest that oil and protein contents are affected by weather, primarily by temperature. Moisture availability through its plant cooling effect may also influence oil and protein content, but this effect is confounded with the temperature effect and to date their relationship has not been characterized. Hot/dry weather favors the increased production of oil and decreased production of protein. Cool temperatures and above normal rainfall favor higher yields and protein contents. The largest determinant of oil and protein content is the genetic makeup of the variety. High protein varieties tend to have lower than average oil contents and high oil varieties tend to have lower than average protein contents (Figure 10), but there are exceptions to these generalities. These observed differences lead to the next portion of this report, which is identifying varieties that yield well and have either high oil, high protein or high % OP contents.

While an individual crushing plant has some control over the production area from which to purchase soybeans for processing, soybean producers are not able to change the environment where their crops are produced. However, both farmers and industry can control the varieties grown and/or purchased for processing. In that vein, both have control of the oil and protein content and can control their competitiveness in both domestic and world markets. Farmers can choose to grow varieties with particular complements of oil and protein and crushers can influence this choice through pricing (premiums). By working together, the U.S. soybean industry has the ability to control its competitiveness in the world market, thus increasing prosperity for both the processing industry and producers. The pursuit of this increased competitiveness necessitates a thorough characterization of the oil and protein contents of each variety followed by the selection and production of varieties most favored in domestic and export markets. Over the past several years the domestic market has preferred high oil content varieties while the export market has preferred high protein varieties. There are many varieties suitable for each market.

Following the previously discussed evaluation of environment and variety effects on grain yield, oil and protein content of 17 varieties, the entire database (oil, protein, yield) was adjusted to remove the site or environmental influence on grain yield, oil and protein content. This adjustment was imposed to make possible a comparison of 452 varieties tested at some but not all test sites. This adjustment consisted of calculating the mean values of % oil, % protein, and yield for each location and then calculating the mean of the location means or grand mean. The location means were then compared to the grand mean. Percent oil, % protein, and yield of each variety at a location were then adjusted by the percent difference in the location mean and the grand mean. In effect, we were able to compare all 452 varieties to one another with a fair degree of confidence. With this data we can identify varieties having specific qualities that meet specific needs. Table 5 contains the means and extremes of this adjusted data, while Tables 6, 7, 8, 9, and 10 contain the top 45 varieties (10%) for % oil, % protein, yield, % OP, and economic yield. Economic yield is the yield of oil multiplied by the price of oil plus the yield of protein multiplied by the price of protein.

Table 3. Oil and protein concentration, yield, and % OP for each of 17 varieties tested at each of nine test sites from 1988 to 1991.

Company	Variety	% Oil	% Protein	Yield (bu/ac)	% OP
Public Certified	Century 84	20.3	42.2	40.9	62.5
AGRA	GR 8936	21.4	41.0	45.5	62.4
Wellman Seeds	W 250	21.6	40.5	45.2	62.2
Public Certified	Resnik	21.0	40.8	47.7	61.8
Thompson Seed Farm	TS 222	21.8	39.9	43.8	61.7
Public Certified	Zane	21.7	39.9	43.0	61.7
Thompson Seed Farm	TS 355	21.3	40.3	43.3	61.6
Public Certified	Flyer	20.5	41.0	47.5	61.5
Public Certified	Harper 87	20.9	40.6	42.4	61.4
Public Certified	Beeson 80	20.8	40.5	39.8	61.3
Public Certified	Pella 86	21.8	39.4	42.4	61.1
Public Certified	Spencer	21.1	40.0	42.4	61.1
French's Hybrids	French's 3470	21.0	40.0	45.0	61.0
Wellman Seeds	W 340	21.6	39.1	45.7	60.7
Thompson Seed Farm	TS 360	20.9	39.7	44.8	60.7
The Ohio Grain Co.	Shurgrow SG387	20.7	39.5	44.2	60.3
Public Certified	Ripley	21.1	38.5	46.3	59.6
	LSD .05	0.48	0.78	3.80	0.68

Table 4. General growing season characteristics (May - September) for each site from 1988 through 1991.

Test Site	Air Temp. (°F)	Prec. (in.)	Solar Radiation (Ly)	Soil Temp. (°F)	Descriptive Terms Temp. - Prec.
1 (88WE)	69.4	13.1	72,007	70.4	Hot - Dry
2 (88NW)	69.1	13.4	73,874	69.1	Hot - Dry
3 (88FF)	69.3	6.3	74,540	69.3	Hot - Dry
4 (89WE)	66.9	21.0	61,636	67.6	Normal - Wet
5 (89NW)	66.1	16.2	72,590	65.3	Normal - Normal
6 (90WE)	67.2	23.8	63,221	68.5	Warm - Wet
7 (90NW)	66.1	22.6	69,734	65.4	Normal - Wet
8 (91WE)	70.7	11.8	74,095	74.5	Hot - Dry
9 (91NW)	69.8	10.6	77,152	73.8	Hot - Dry

*1 = 1988 Western Branch OARDC
2 = 1988 Northwest Branch OARDC
3 = 1988 Farm Focus
4 = 1989 Western Branch OARDC
5 = 1989 Northwest Branch OARDC
6 = 1990 Western Branch OARDC
7 = 1990 Northwest Branch OARDC
8 = 1991 Western Branch OARDC
9 = 1991 Northwest Branch OARDC

Figure 2: Change in oil and protein with production site.

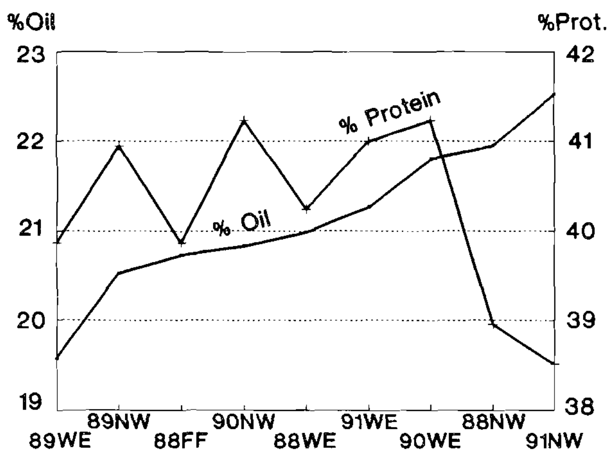
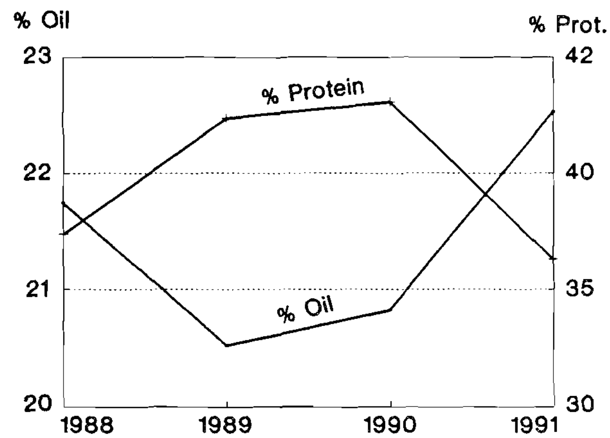


Figure 3: Mean oil and protein content of 17 varieties at the NW Branch OARDC, 1988-1991.



These Tables (6-10) can be used to identify varieties with specific grain characteristics needed to satisfy a specialty market requirement. The varieties in a specific table may not really be distinct from one another since the numbers of observations used to calculate the means differed. However, the varieties found within a particular table are among the best for the characteristic on which the table is sorted, i.e. the bold face column. When comparing the column means of Tables 6-10, note how the mean for each characteristic changes as the data base was sorted on different characteristics. For example, the oil and protein means in Tables 6 and 7 are substantially different. When high oil content was selected the protein mean is much lower than when high protein was selected. The relationships between oil or protein content and grain and economic yield lead to some very interesting speculation.

Summary

We have heard that the quality of American soybeans is inferior to that of competing exporting countries. The Japanese and Europeans have assembled data indicating that South American soybeans are consistently higher in oil and protein and contain less FM than U.S. soybeans. As a result, the U.S. has become a last-resort source of soybeans for the world market. In a highly competitive industry, we cannot ignore the

Figure 4: Mean yield, oil and protein content of 17 varieties for each of nine production sites.

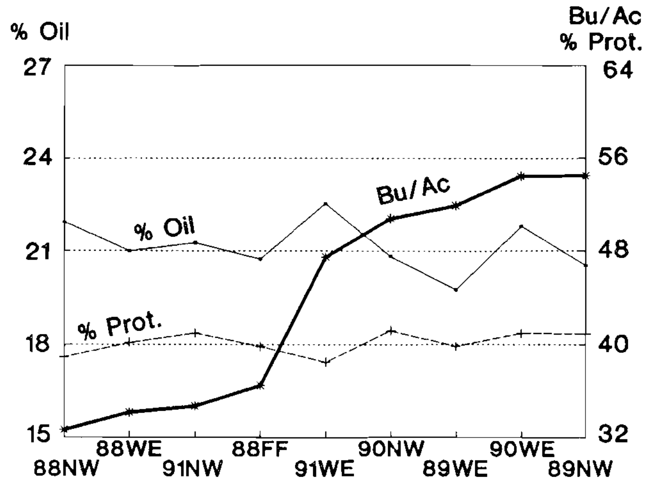


Figure 5: Correlations for May - Sept. environmental factors with yield and yield components.

	Air Temp.	Prec.	Solar Radiation	Soil Temp.
Yield	-0.72	+0.75	-0.65	-0.54
% Oil	+0.45	-0.46	+0.37	+0.28
% Protein	-0.47	+0.61	-0.40	-0.42
% OP	-0.27	+0.62	-0.27	-0.16

Figure 6: Effect of mean daily May - Sept. air temperature on grain yield, % oil, and % protein.

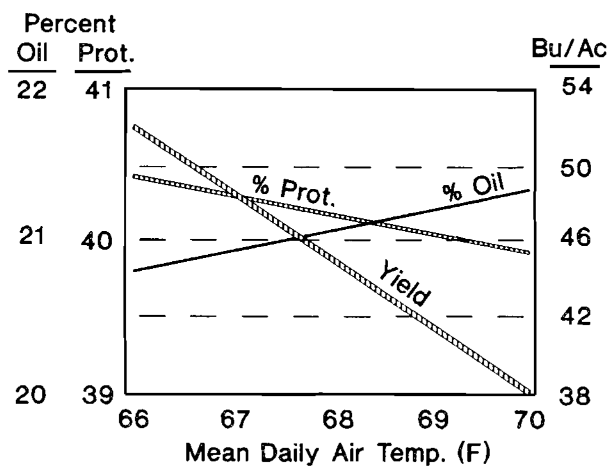


Figure 7: Effect of mean May - Sept. rainfall on grain yield, % oil and % protein.

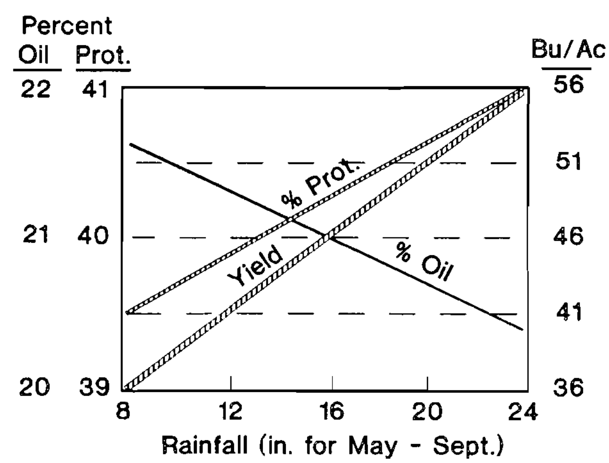


Figure 8: Effect of mean May - Sept. solar energy (Langleys) on grain yield, % oil, and % protein.

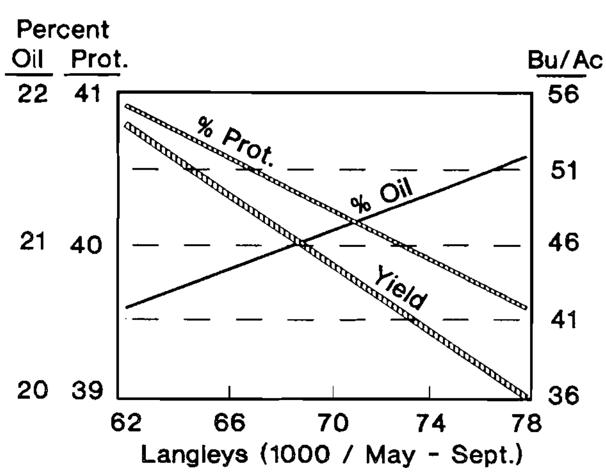
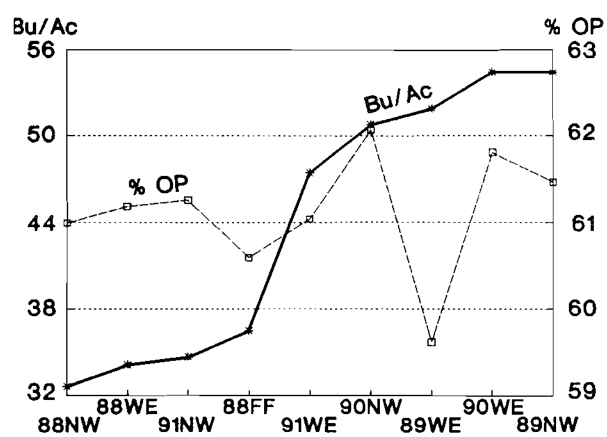


Figure 9: Mean yield and % OP of 17 varieties for each of nine production sites.



complaints of valued customers. Soybean contracts with U.S. customers are based on the weight and grade at the time a ship is loaded. We know that deterioration, both physically and biologically, occurs during handling, transport and storage in the destination country. Because the quality sometimes changes during shipping, customers do not always receive what they ordered, which is a valid complaint. The Federal Grain Inspection Service is attempting to address some of these concerns through regulation by proposing a tightening of standards for grades of U.S. soybeans. However, regaining dominance of the world soybean market is ultimately in the hands of both soybean producers and exporters since they determine the varieties grown, therefore oil and protein content, and quality of soybeans exported. Whether the production of high oil-protein varieties and reduced foreign matter is legislated or self-selected by producers and industry, it must occur if we are to increase our world market competitiveness by producing a superior product. The data contained herein helps explain why oil and protein content changes and identifies 45 outstanding varieties (Tables 6-10) for yield and each of several soybean characteristics.

It seems logical that shipping and processing cost will eventually increase and encourage industry to pay premiums for higher contents of oil and protein and reduced FM. When this happens, producers will likely grow different varieties, plant breeders will develop higher quality varieties, and U.S. soybeans will again be highly desirable on the world market leading to increased competitiveness for U.S. producers. The process should then snowball, leading to greater market share and better profits. To date (1992), neither producers nor industry have been willing to make that snowball and give it a push downhill. Perhaps American soybean producers should take the lead by growing varieties with higher oil and protein contents. The effect would be that exporters could have a higher quality product to sell and a quality conscious world should rush to our store.

Figure 10: Mean % oil, % protein and % OP averaged over nine production sites.

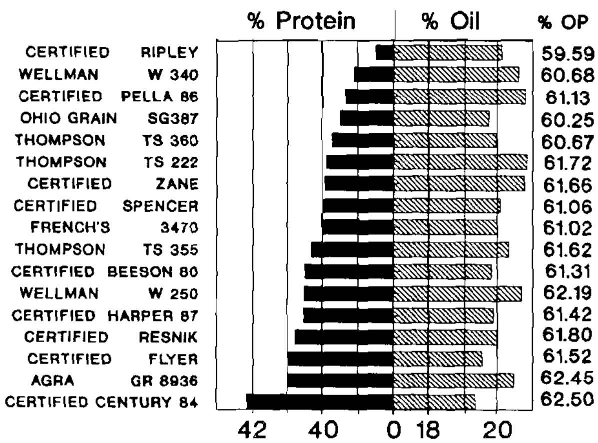


Figure 11: Mean % oil, % protein, and yield of 17 soybean varieties averaged over nine production sites.

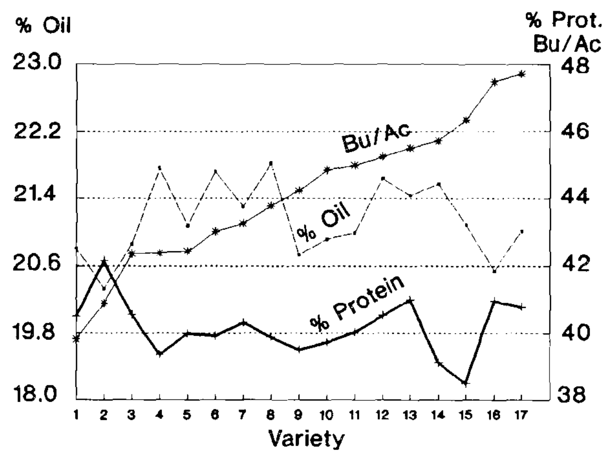


Table 5. Maximum, mean, and minimum means for % protein, % oil, yield, % OP, and economic yield of 452 soybean varieties following adjustments for site differences.

Variable	Maximum	Mean	Minimum
% Oil	23.4	21.2	19.3
% Protein	42.9	40.1	37.2
Yield (bu/ac)	52.2	42.3	27.7
% OP	63.6	61.3	58.5
Economic Yield ($/ac)	435	355	227

The mean + and - a standard deviation value include 68% of varieties tested.
The mean + and - 2 standard deviations would include 95% of varieties tested.

Table 6. Number of observations, % oil, % protein, yield (bu/ac), % OP, and economic yield ($/ac) of the 45 varieties with the highest % oil sorted in decreasing order.

Company	Variety	No. of Observ.*	% Oil	% Prot.	Yield	% OP	Econ. Yld.
Lynks Seeds	LX 8280	1	**23.41**	38.89	45.83	62.30	385.45
Edward J. Funk & Sons	Amer. Champion	2	**22.81**	38.11	40.30	60.92	331.44
Northrup King Co.	S 23-12	4	**22.66**	39.17	36.51	61.83	304.75
Pioneer Hi-Bred Int'l	Pioneer 9271	1	**22.64**	38.99	34.61	61.63	287.96
Pioneer Hi-Bred Int'l	Pioneer 9311	2	**22.61**	38.62	46.79	61.23	386.77
Northrup King Co.	B 236	2	**22.58**	37.43	41.13	60.01	333.21
Steyer Seeds	Steyer 200	2	**22.58**	38.92	34.02	61.50	282.45
Cargill	Cargill 277	2	**22.53**	38.11	45.86	60.64	375.43
Public Certified	Hobbit 87	2	**22.49**	39.20	37.89	61.69	315.55
Golden Harvest	Harvest H-1278	3	**22.49**	40.92	40.05	63.41	342.84
J. M. Schultz Seed	JMS 2987	2	**22.46**	38.94	40.01	61.40	331.64
Public Certified	Chapman	2	**22.39**	39.69	49.13	62.08	411.75
Public Certified	Elgin	3	**22.36**	38.49	42.25	60.85	347.07
Dairyland Seed Co.	DSR 252	6	**22.32**	39.99	37.03	62.31	311.49
Asgrow Seed Co.	A 2396	4	**22.31**	38.99	37.73	61.30	312.23
Public Certified	Sprite 87	5	**22.31**	39.33	40.05	61.64	333.27
Lynks Seeds	LX 8307	3	**22.25**	38.35	39.07	60.60	319.63
Dairyland Seed Co.	DST 3111	2	**22.23**	39.08	45.25	61.31	374.53
Agracetus Inc.	Agracetus 108	2	**22.23**	38.67	34.07	60.90	280.11
Madison Seed Co.	121052	1	**22.22**	39.49	43.06	61.71	358.73
Steyer Seeds	Steyer Hayes	2	**22.22**	37.64	43.36	59.86	350.40
Terra Int'l.	Sprint	6	**22.21**	39.85	43.69	62.06	366.04
Pioneer Hi-Bred Int'l	Pioneer 9301	7	**22.21**	39.20	43.74	61.41	362.62
Callahan Seeds	Callahan 7260	2	**22.19**	39.41	38.95	61.60	323.91
The Humphrey Farm	Stackhouse 290	5	**22.18**	38.05	42.03	60.23	341.75
Great Lakes Hybrids	GL 3788	4	**22.18**	38.88	42.04	61.06	346.54
Golden Harvest	H-1271	2	**22.17**	39.25	41.83	61.42	346.84
Seedex	Seedex 370	2	**22.17**	39.14	46.08	61.31	381.40
Golden Harvest	Harvest X 260	2	**22.17**	38.39	40.58	60.56	331.77
Wellman Seeds	W 371	4	**22.16**	39.11	44.58	61.27	368.74
Public Certified	Elgin 87	5	**22.15**	38.14	40.94	60.29	333.22
Golden Harvest	H-1260	4	**22.13**	38.32	42.72	60.45	348.63
Rupp Seeds	RS 2490	2	**22.13**	39.08	39.34	61.21	325.08
Ciba-Geigy Seed Div.	Funk's G3300	2	**22.11**	40.22	44.38	62.33	373.44
Dairyland Seed Co.	DSR 270	7	**22.11**	40.99	43.01	63.10	366.38
Callahan Seeds	Callahan 7299	6	**22.07**	38.81	43.18	60.88	354.89
Public Certified	Pella	7	**22.04**	38.34	42.20	60.38	343.98
Agripro	Agripro EX 2740	2	**22.04**	39.65	41.21	61.69	343.20
Countrymark	FFR 253	4	**22.04**	38.70	41.72	60.74	342.10
King Agro	KG 120	1	**22.03**	39.09	45.42	61.12	374.77
AgriPro	Agripro AP 2324	4	**22.02**	39.25	36.12	61.27	298.76
Golden Harvest	Harvest H-1289	2	**22.01**	38.18	39.28	60.19	319.18
The Humphrey Farm	Stackhouse 180	5	**22.00**	39.24	27.76	61.24	229.50
Wellman Seeds	Warren	5	**21.97**	38.89	44.05	60.86	361.92
Provico Seeds	Pro 2290	3	**21.95**	37.87	42.81	59.82	345.72
		MEANS	**22.23**	38.96	41.15	61.23	340.16

*Accuracy increases with the number of observations.

Table 7. Number of observations, % protein, yield (bu/ac), % OP, economic yield ($/ac), and % oil of the 45 varieties with the highest % protein sorted in decreasing order.

Company	Variety	No. of Observ.*	% Prot.	Yield	% OP	Econ. Yld.	% Oil
Pro-Seed Inc.	PS 80-87-C14	2	**42.94**	39.28	62.68	332.38	19.74
Ruff's Seed Farm	EXP 300	2	**42.78**	43.04	63.52	369.08	20.74
Ruff's Seed Farm	RF 3100	4	**42.68**	42.90	62.32	360.93	19.64
Dairyland Seed Co.	DSR 177	1	**42.60**	36.90	62.64	227.48	20.04
J. M. Schultz Seed	JMS 3809	1	**42.48**	35.13	62.43	296.08	19.95
Ruff's Seed Farm	EXP 100	2	**42.31**	49.55	63.23	422.96	20.92
Gries Seed Farms	GSF 390	2	**42.24**	40.61	62.00	339.91	19.76
Public Certified	Century 84	9	**42.17**	40.90	62.51	345.15	20.34
Pro-Seed Inc.	PS 80-87-22	2	**42.12**	41.30	62.45	348.19	20.33
King Agro	GG 3200	4	**42.09**	44.56	62.94	378.62	20.85
Uphoff Seeds	EX UP B-1017	2	**42.07**	45.09	62.60	381.06	20.53
Ruff's Seed Farm	RF 2600	4	**42.06**	41.42	62.07	347.08	20.01
Diener	DB 308	1	**42.03**	47.75	62.33	401.79	20.30
Rupp Seeds	RS 2444	4	**42.02**	37.61	63.55	322.67	21.53
Asgrow Seed Co.	A 3733	2	**42.01**	41.90	63.34	358.28	21.33
Northrup King Co.	S 28-18	2	**42.01**	44.99	62.35	378.69	20.34
Asgrow Seed Co.	A 3803	1	**41.98**	39.01	62.13	327.20	20.15
Public Certified	Burlison	6	**41.93**	42.83	61.98	358.37	20.05
Wellman Seeds	W 370	2	**41.92**	39.06	62.51	329.62	20.59
Asgrow Seed Co.	A 2543	6	**41.90**	40.57	62.90	344.50	21.00
Madison Seed Co.	GL 4210	2	**41.86**	37.21	62.66	314.76	20.80
Countrymark	FFR 352	4	**41.78**	51.59	62.16	432.92	20.38
UAP Seeds	Dyna-Gro 3233	2	**41.78**	47.17	62.22	396.21	20.44
Rupp Seeds	RS 2525	2	**41.74**	44.46	63.13	378.91	21.39
Dewine	Gold Bag 405	1	**41.68**	46.37	61.33	383.92	19.65
Voris Seeds	Voris 239	3	**41.66**	39.14	62.77	331.67	21.11
Northrup King Co.	S 42-30	4	**41.65**	45.56	62.53	384.60	20.88
Adler Seeds	Adler 299	4	**41.65**	42.24	62.29	355.20	20.64
Madison Seed Co.	GL 3620	4	**41.61**	44.44	62.35	374.06	20.74
Northrup King Co.	S 39-11	2	**41.59**	45.46	62.01	380.56	20.42
Seedex	Seedex 253	1	**41.57**	32.98	62.77	279.47	21.20
Good Buddy Seeds	GoodBuddy GB30	2	**41.57**	44.99	61.99	376.51	20.42
The Ohio Grain Co.	Shurgrow SG384	5	**41.53**	45.48	61.46	377.35	19.93
Madison Seed Co.	GL 3100	3	**41.47**	39.20	62.63	331.44	21.16
Golden Acres Seed Co.	GA 8279	2	**41.47**	43.66	62.06	365.79	20.59
Gries Seed Farms	GSF 265	2	**41.46**	40.76	62.33	342.98	20.87
Wellman Seeds	W 440	3	**41.45**	39.34	61.25	325.29	19.80
Steyer Seeds	Steyer 330	7	**41.42**	42.19	61.25	348.86	19.83
AgriPro	AgriPro AP 3773	5	**41.36**	43.36	62.67	366.85	21.31
Dairyland Seed Co.	DST 2107	1	**41.36**	34.74	61.59	288.85	20.23
Public Certified	Keller	3	**41.35**	40.28	62.18	338.12	20.83
Provico Seeds	Pro 2260	2	**41.33**	45.11	62.73	382.02	21.40
Ruff's Seed Farm	RS 3500	2	**41.32**	40.10	61.58	333.36	20.26
Steyer Seeds	Steyer 380	2	**41.31**	38.74	61.62	322.27	20.31
Pioneer Hi-Bred Int'l	Pioneer 9392	2	**41.31**	49.21	62.36	414.28	21.05
		MEANS	**41.83**	42.18	62.36	353.25	20.53

*Accuracy increases with the number of observations.

Table 8. Number of observations, yield (bu/ac), % OP, economic yield ($/ac), % oil, and % protein of the 45 varieties with the highest yield sorted in decreasing order.

Company	Variety	No. of Observ.*	**Yield**	% OP	Econ. Yld.	% Oil	% Prot.
Beck's Hybrids	Beck 388	3	**52.22**	60.52	426.65	20.53	39.99
Agripro	Agripro EX 3800	2	**52.08**	61.88	435.07	20.98	40.90
Countrymark	FFR 352	2	**51.59**	62.16	432.92	20.38	41.78
Andersons	Nosco 350	2	**51.11**	61.51	424.41	21.55	39.96
Golden Harvest	X-335	2	**51.04**	61.89	426.45	21.03	40.86
The Ohio Grain Co.	Shurgrow SG351	4	**50.90**	60.88	418.34	21.09	39.79
Leader Seeds	Leader L330	2	**50.72**	61.78	423.02	20.74	41.04
Provico Seeds	Pro 3390	2	**50.66**	61.04	417.46	21.40	39.64
Terra Int'l.	Torch	2	**50.38**	60.72	412.97	20.61	40.11
The Ohio Grain Co.	Shurgrow SG292	2	**49.97**	61.06	411.91	21.43	39.63
The Ohio Grain Co.	EXP 3899	1	**49.80**	61.02	410.24	20.20	40.82
Madison Seed Co.	GL 3410	2	**49.76**	61.24	411.39	20.33	40.91
Beck's Hybrids	Beck 337	5	**49.68**	61.61	413.21	20.67	40.94
UAP Seeds	Dyna-Gro 3290	2	**49.66**	60.20	403.59	21.22	38.98
Donley Seed Co.	JMS 800	2	**49.65**	60.88	408.06	21.43	39.45
Golden Harvest	H-1380	2	**49.64**	61.18	409.99	21.24	39.94
Callahan Seeds	Callahan 1365	2	**49.55**	61.38	410.59	20.78	40.60
Ruff's Seed Farm	EXP 100	2	**49.55**	63.23	422.96	20.92	42.31
Voris Seeds	Voris 379	3	**49.44**	60.78	405.67	20.49	40.29
Edward J. Funk & Sons	Diamond D301	2	**49.27**	61.00	405.74	20.75	40.25
Stine Seed Farm	Stine 3090E	2	**49.24**	60.00	398.84	20.67	39.33
AgriPro	AgriPro AP 3550	2	**49.21**	60.33	400.79	20.48	39.85
Rupp Seeds	RS 2500	3	**49.21**	61.87	411.02	21.69	40.18
Pioneer Hi-Bred Int'l	Pioneer 9392	2	**49.21**	62.36	414.28	21.05	41.31
Prairie Stream Farms	PSF 368A	2	**49.18**	60.89	404.27	20.90	39.99
French's Hybrids	French's 3310	4	**49.16**	61.35	407.16	21.57	39.78
Public Certified	Chapman	2	**49.13**	62.08	411.75	22.39	39.69
Ruff's Seed Farm	EXP 200	2	**48.99**	61.35	405.75	21.71	39.64
Terra Int'l.	Flame	2	**48.96**	60.07	397.04	20.50	39.57
DEKALB Plant Genetics	DEKALB CX267	2	**48.95**	61.18	404.29	21.93	39.25
UAP Seeds	Dyna-Gro 3270	2	**48.70**	60.25	396.11	21.22	39.03
King Agro	GG 2700	2	**48.57**	60.89	399.25	21.34	39.55
Dairyland Seed Co.	DSR 317	1	**48.47**	61.14	400.07	21.12	40.02
Pioneer Hi-Bred Int'l	Pioneer 9273	4	**48.47**	61.42	401.90	21.95	39.47
Callahan Seeds	Callahan 2399x	2	**48.43**	61.78	403.92	20.56	41.22
Leader Seeds	Leader L 340	4	**48.35**	61.97	404.49	20.81	41.16
Stine Seed Farm	Stine 3220	2	**48.29**	60.41	393.82	21.33	39.08
Rupp Seeds	RS 2585	4	**48.28**	60.96	397.33	19.76	41.20
Provico Seeds	Pro 3330	4	**48.22**	61.42	399.83	20.82	40.60
Maumee Valley Seeds	MV-7097	2	**48.20**	60.40	393.02	20.34	40.06
Public Certified	Edison	2	**48.15**	61.11	397.23	21.01	40.10
Donley Seed Co.	JMS 705	2	**47.97**	61.62	399.05	21.69	39.93
Callahan Seeds	Callahan 2383x	2	**47.97**	60.63	392.64	20.71	39.92
Edward J. Funk & Sons	Diamond D305	2	**47.88**	60.53	391.25	21.44	39.09
Good Buddy Seeds	GoodBuddy GB48	2	**47.87**	61.77	399.19	20.95	40.82
		MEANS	**49.37**	61.20	407.89	21.02	40.18

*Accuracy increases with the number of observations.

Table 9. Number of observations, % OP, economic yield ($/ac), % oil, % protein, and yield (bu/ac) of the 45 varieties with the highest % OP sorted in decreasing order.

Company	Variety	No. of Observ.*	**% OP**	Econ. Yld.	% Oil	% Prot.	Yield
Rupp Seeds	RS 2444	2	**63.55**	322.67	21.53	42.02	37.61
Ruff's Seed Farm	EXP 300	2	**63.52**	369.08	20.74	42.78	43.04
Golden Harvest	Harvest H-1278	3	**63.41**	342.84	22.49	40.92	40.05
Asgrow Seed Co.	A 3733	2	**63.34**	358.28	21.33	42.01	41.90
Ruff's Seed Farm	EXP 100	2	**63.23**	422.96	20.92	42.31	49.55
Rupp Seeds	RS 2525	2	**63.13**	378.91	21.39	41.74	44.46
Dairyland Seed Co.	DSR 270	7	**63.10**	366.38	22.11	40.99	43.01
King Agro	GG 3200	4	**62.94**	378.62	20.85	42.09	44.56
Asgrow Seed Co.	A 2543	6	**62.90**	344.50	21.00	41.90	40.57
Madison Seed Co.	GL 2420	6	**62.88**	367.14	21.82	41.06	43.25
Golden Harvest	Harvest H-1265	3	**62.80**	322.84	21.91	40.89	38.08
Voris Seeds	Voris 239	3	**62.77**	331.67	21.11	41.66	39.14
Seedex	Seedex 253	1	**62.77**	279.47	21.20	41.57	32.98
Lynks Seeds	5288	1	**62.73**	290.81	21.68	41.05	34.34
Provico Seeds	Pro 2260	2	**62.73**	382.02	21.40	41.33	45.11
Pro-Seed Inc.	PS 80-87-C14	2	**62.68**	332.38	19.74	42.94	39.28
AgriPro	AgriPro AP 3773	5	**62.67**	366.85	21.31	41.36	43.36
Madison Seed Co.	GL 4210	2	**62.66**	314.76	20.80	41.86	37.21
Dairyland Seed Co.	DSR 177	1	**62.64**	227.48	20.04	42.60	36.90
Madison Seed Co.	GL 3100	3	**62.63**	331.44	21.16	41.47	39.20
Uphoff Seeds	EX UP B-1017	2	**62.60**	381.06	20.53	42.07	45.09
Provico Seeds	Pro 2250	7	**62.53**	381.90	21.78	40.75	45.24
Northrup King Co.	S 42-30	5	**62.53**	384.60	20.88	41.65	45.56
Public Certified	Century 84	9	**62.51**	345.15	20.34	42.17	40.90
Wellman Seeds	W 370	2	**62.51**	329.62	20.59	41.92	39.06
AGRA	GR 8936	7	**62.48**	384.54	21.45	41.03	45.59
Pro-Seed Inc.	PS 80-87-22	2	**62.45**	348.19	20.33	42.12	41.30
Scott	Scott L 4088	1	**62.44**	366.93	21.26	41.18	43.53
J. M. Schultz Seed	JMS 3809	1	**62.43**	296.08	19.95	42.48	35.13
Steyer Seeds	Steyer 240	4	**62.39**	307.26	21.13	41.26	36.48
Rupp Seeds	RS 2544	4	**62.38**	371.04	21.64	40.74	44.06
Pioneer Hi-Bred Int'l	Pioneer 9392	2	**62.36**	414.28	21.05	41.31	49.21
Northrup King Co.	S 28-18	2	**62.35**	378.69	20.34	42.01	44.99
Asgrow Seed Co.	A 2943	5	**62.35**	370.36	21.63	40.72	44.00
Madison Seed Co.	GL 3620	4	**62.35**	374.06	20.74	41.61	44.44
King Grain	KG 81	1	**62.34**	243.47	21.29	41.05	28.93
Gries Seed Farms	GSF 265	2	**62.33**	342.98	20.87	41.46	40.76
Diener	DB 308	1	**62.33**	401.79	20.30	42.03	47.75
Ciba-Geigy Seed Div.	Funk's G3300	2	**62.33**	373.44	22.11	40.22	44.38
Ruff's Seed Farm	RF 3100	4	**62.32**	360.93	19.64	42.68	42.90
Dairyland Seed Co.	DSR 252	6	**62.31**	311.49	22.32	39.99	37.03
Lynks Seeds	LX 8280	1	**62.30**	385.45	23.41	38.89	45.83
Adler Seeds	Adler 299	4	**62.29**	355.20	20.64	41.65	42.24
Madison Seed Co.	GL 2820	3	**62.23**	357.63	21.22	41.01	42.57
AgriPro	AgriPro AP 3023	4	**62.23**	363.51	20.96	41.27	43.27
		MEANS	**62.64**	350.24	21.13	41.51	41.64

*Accuracy increases with the number of observations.

Table 10. Number of observations, economic yield ($/ac), % oil, % protein, yield (bu/ac), and % OP of the 45 varieties with the highest economic yield sorted in decreasing order.

Company	Variety	No. of Observ.*	Econ. Yld.	% Oil	% Prot.	Yield	% OP
Agripro	Agripro EX 3800	2	**435.07**	20.98	40.90	52.08	61.88
Countrymark	FFR 352	2	**432.92**	20.38	41.78	51.59	62.16
Beck's Hybrids	Beck 388	3	**426.65**	20.53	39.99	52.22	60.52
Golden Harvest	X-335	2	**426.45**	21.03	40.86	51.04	61.89
Andersons	Nosco 350	2	**424.41**	21.55	39.96	51.11	61.51
Leader Seeds	Leader L330	2	**423.02**	20.74	41.04	50.72	61.78
Ruff's Seed Farm	EXP 100	2	**422.96**	20.92	42.31	49.55	63.23
The Ohio Grain Co.	Shurgrow SG351	4	**418.34**	21.09	39.79	50.90	60.88
Provico Seeds	Pro 3390	2	**417.46**	21.40	39.64	50.66	61.04
Pioneer Hi-Bred Int'l	Pioneer 9392	2	**414.28**	21.05	41.31	49.21	62.36
Beck's Hybrids	Beck 337	5	**413.21**	20.67	40.94	49.68	61.61
Terra Int'l.	Torch	2	**412.97**	20.61	40.11	50.38	60.72
The Ohio Grain Co.	Shurgrow SG292	2	**411.91**	21.43	39.63	49.97	61.06
Public Certified	Chapman	2	**411.75**	22.39	39.69	49.13	62.08
Madison Seed Co.	GL 3410	2	**411.39**	20.33	40.91	49.76	61.24
Rupp Seeds	RS 2500	3	**411.02**	21.69	40.18	49.21	61.87
Callahan Seeds	Callahan 1365	2	**410.59**	20.78	40.60	49.55	61.38
The Ohio Grain Co.	EXP 3899	1	**410.24**	20.20	40.82	49.80	61.02
Golden Harvest	H-1380	2	**409.99**	21.24	39.94	49.64	61.18
Donley Seed Co.	JMS 800	2	**408.06**	21.43	39.45	49.65	60.88
French's Hybrids	French's 3310	4	**407.16**	21.57	39.78	49.16	61.35
Ruff's Seed Farm	EXP 200	2	**405.75**	21.71	39.64	48.99	61.35
Edward J. Funk & Sons	Diamond D301	1	**405.74**	20.75	40.25	49.27	61.00
Voris Seeds	Voris 379	3	**405.67**	20.49	40.29	49.44	60.78
Leader Seeds	Leader L 340	4	**404.49**	20.81	41.16	48.35	61.97
DEKALB Plant Genetics	DEKALB CX267	2	**404.29**	21.93	39.25	48.95	61.18
Prairie Stream Farms	PSF 368A	2	**404.27**	20.90	39.99	49.18	60.89
Callahan Seeds	Callahan 2399x	2	**403.92**	20.56	41.22	48.43	61.78
UAP Seeds	Dyna-Gro 3290	2	**403.59**	21.22	38.98	49.66	60.20
Pioneer Hi-Bred Int'l	Pioneer 9273	4	**401.90**	21.95	39.47	48.47	61.42
Diener	DB 308	1	**401.79**	20.30	42.03	47.75	62.33
AgriPro	AgriPro AP 3550	2	**400.79**	20.48	39.85	49.21	60.33
Dairyland Seed Co.	DSR 317	1	**400.07**	21.12	40.02	48.47	61.14
Provico Seeds	Pro 3330	4	**399.83**	20.82	40.60	48.22	61.42
Public Certified	Resnik	9	**399.37**	21.03	40.82	47.83	61.85
King Agro	GG 2700	2	**399.25**	21.34	39.55	48.57	60.89
Good Buddy Seeds	GoodBuddy GB48	2	**399.19**	20.95	40.82	47.87	61.77
Donley Seed Co.	JMS 705	2	**399.05**	21.69	39.93	47.97	61.62
Stine Seed Farm	Stine 3090E	2	**398.84**	20.67	39.33	49.24	60.00
Wellman Seeds	W 360	4	**398.54**	20.92	40.75	47.87	61.67
Donley Seed Co.	JMS 796	2	**398.45**	21.07	40.91	47.62	61.98
Ruff's Seed Farm	Adams	4	**398.18**	21.19	40.54	47.78	61.73
Madison Seed Co.	GL 1910	6	**397.73**	21.17	40.49	47.78	61.66
Rupp Seeds	RS 2585	4	**397.33**	19.76	41.20	48.28	60.96
Public Certified	Edison	2	**397.23**	21.01	40.10	48.15	61.11
		MEANS	**408.56**	21.02	40.37	49.30	61.39

*Accuracy increases with the number of observations.