Breeding for Improved Oilseeds[1]

R.W. HOWELL, Plant Science Research Division, ARS, USDA
Beltsville, Maryland

ABSTRACT

Breeding for improved oilseeds has traditionally emphasized improvement in yield, oil content and disease resistance. Improved protein has been sought by some breeders in recent years. The soybean varieties Provar and Protana were released in 1969 because they contain higher protein percentages than other varieties. Glandless cotton varieties are being bred by public and private breeders. Two glandless varieties have been released by commercial breeder-seedsmen, but one has been withdrawn because of low yield. It probably will be several years before glandless varieties are of commercial significance. Safflower germplasm has been screened and a source of improved lysine has been identified. This lead may be pursued, but major problems of disease susceptibility and high fiber content also demand attention. Emphasis in sunflower programs will be on developing higher yielding lines and on exploiting the possibility of developing hybrids. Sunflower research personnel is so limited that there is not likely to be any major effort on quality factors for some time. Sesame research is very limited, major emphasis being on control of shattering.

Oilseed production research has primarily emphasized increased crop yields and higher oil contents. Until very recently there has been little encouragement for research emphasis on higher or improved protein content from farmers, from industry or from national policy makers.

The growing appreciation of the importance of protein diets has provided a respectability for protein emphasis in oilseed breeding programs. The dramatic improvement in amino acid distribution in corn conditioned by the opaque 2 gene has stimulated scientists to seek comparable improvement in other commodities.

Soybeans

Plant breeders and geneticists, of necessity, take a long view. Thus several soybean breeders introduced protein improvement as an objective into their programs many years ago. E.E. Hartwig's protein breeding work in soybeans at Stoneville, Miss., dates back at least to 1948. The late L.F. Williams began about the same time at Urbana, Ill., later working at Columbia, Mo. C.R. Weber, Ames, Iowa, and A.H. Probst, Lafayette, Ind., had high protein lines in their programs 15 years or more ago.

The problem of improving protein was both mathematical and biological: How to increase the major constituents of soybeans (oil and protein), both of which represent more energy per pound than the carbohydrates which they would displace, while also increasing yield per acre? Without increasing yield or at least maintaining yield, a price differential is needed as an incentive for a farmer to grow a new variety.

The first soybean variety selected on the basis of a protein content was released in May 1969. This was the variety, Provar. A second such variety, Protana, was released in August 1969. Provar averages about 43% protein and Protana about 42.5%, compared with a range from 38.7% to 40.5% for several standard varieties grown competitively in four-year regional tests. They each have about 20% oil as compared with 21% to 22% for standard varieties (Table I).

The two varieties, both of which are adapted in the Iowa, Illinois and Indiana area, yield about the same. Provar is about four days earlier than Protana, and has a little larger seed.

There are high protein lines in our southern program also, but none has been released. One of these has a protein content of about 45% and yields about the same as Hood.

It will be at least another year before any beans of these varieties appear in the market. They cannot reach substantial quantities before 1973. Neither of the varieties released, nor the lines in advanced testing, meet the ideal criterion of higher oil, higher protein and higher yield. They do have yields and product values about equal to those of other varieties available to growers.

The acceptance of these varieties will be watched very closely. It is technically possible to increase protein further and more rapidly. Appropriate germplasm is now in breeding programs. Research to increase protein would be at the expense of research to increase yield and oil.

In establishing priorities for protein research in soybeans it must be recognized that soybeans are already high in well-balanced protein. Soybeans produce the most protein per acre of any seed crop. An average increase in yield of one bushel per acre in the United States would produce additional protein equivalent to the total annual needs of 17 million people and would contribute proportionately to meeting calorie requirements. Thus an increased emphasis on protein at the expense of improving yield is of doubtful value in soybeans.

There has been little interest in breeding for changes in amino acids in soybeans. Unlike the cereals and several other oilseeds, lysine is adequate in soybeans (Table II). Methionine is the first nutritionally limiting amino acid, but when methionine plus cystine is considered, the deficiency is reduced. Therefore, we give a low priority to breeding for changes in amino acids in soybeans.

Although the soybean is the dominant oilseed in the marketplace and has the largest potential among oilseeds for significance in protein problems, there are interesting developments in other oilseeds.

Glandless Cotton

Glandless cotton is characterized by the absence of glands containing gossypol which occur in the seeds and elsewhere in standard varieties of cotton (C.F. Lewis, private communication). Glandless cotton meal is a little lighter in color than meal of glanded varieties. However, the amino acid composition of protein from glandless cottonseed is very similar to that from glanded (C.F. Lewis, R.J. Miravalle and K. Smith, private communications).

Two glandless cotton varieties have been released. They are 'Gregg 25V' and 'Watson GL-16.' Each was developed by a commercial breeder-seedsman. Gregg 25V has been withdrawn because of low yield of lint. Reliable estimates of lint yield of Watson GL-16 are not available, but it was sold again in 1970. Each of these varieties was marketed in the Lubbock, Texas, area.

Glandless cotton is included in the programs of all commercial breeders and most state and federal breeders.

[1]One of 21 papers presented at the Symposium, "Oilseed Processors Challenged by World Protein Need," ISF-AOCS World Congress, Chicago, September 1970.

TABLE I

Composition and Value of
High Protein and Standard Soybean Varieties[1]

Regions	Oil, %	Protein, %	Yield, bu	Value per acre[2]
Northern varieties				
Amsoy	22.0	38.7	39.7	137.84
Harosoy 63	21.0	40.5	37.1	121.91
Provar[3]	20.4	43.1	38.2	128.66
Protana[3]	20.2	42.5	37.3	124.10
Southern varieties				
Hood	21.4	39.7	34.9	114.19
Lee	20.9	40.6	36.3	119.13
D60-9647[3]	18.8	45.0	35.0	117.36

[1]Oil, protein and yield data are averages of regional tests for four (northern) and three years (southern).

[2]Based on prices of oil and meal on 1-28-71, after adjusting prices to protein basis.

[3]High protein varieties.

However, increased lint yield has been and is expected to continue as a primary breeding objective. The glandless character, which is conditioned by two recessive genes, has been transferred into a wide spectrum of germplasm at Stoneville, Miss., and Shafter, Calif. Generally, lines arising from these germplasm pools have been low in lint yield. Geneticists are now studying the causes of the low lint yield. An encouraging fact is that several glandless lines with superior yield and excellent lint quality have been observed in a program at Louisiana State University.

R.J. Miravalle, of the National Cottonseed Products Association, predicts that glandless cotton will become established first in the South Plains area around Lubbock, Texas, followed by Oklahoma, other parts of Texas, Arkansas, Louisiana, the Mid-South and Southeast in that order. Glandless varieties are expected to be available for those areas by the mid-1970s. Dr. Miravalle does not expect to see glandless cotton for New Mexico, Arizona and California, until some time in the 1980s.

What will it take to establish glandless cotton? It will require a market and a crop value which makes glandless varieties attractive to the grower. The major value of the cotton crop will probably continue to be lint, so, lint yield must be competitive with that of glanded varieties. It is unlikely that a premium value for glandless seed, sufficient to offset a demonstrable loss in lint yield, could be achieved. Changes in cultural practices, such as a shift to narrower rows, may favor glandless varieties. Developments in processing research to remove gossypol may make elimination of the glands an academic matter.

TABLE III

Composition of Certain Sunflower Varieties[a]

Variety	Oil in kernels, %	Protein in kernels, %	Protein in achenes, %
VNIIMK 8931	68.9	12.2	9.2
Kruglik A-41	66.8	14.9	8.3
Peredovik	69.3	12.4	9.3
Fooksinka 62	66.0	15.1	8.9

[a]Data of Panchenko and Dyakov (6).

It has been suggested that glandless varieties may be more susceptible to insect damage than normal varieties. A prominent cotton entomologist in Georgia recently told me that such is the case. Entomologists of the University of California, however, report that attacks of usual cotton pests have been approximately the same on glanded and glandless cotton in that state (1). Conceivably, glandless cotton may be subject to attack by some pests that do not usually feed on cotton, but that is speculative at this time.

Safflower

Safflower protein is low in lysine, averaging about 2.8% of the nitrogen, or about two thirds of the FAO provisional standard (4) (Table II). Palter et al., have screened more than 2000 safflower lines in the U.S. collection (5). Several lines had lysine levels higher than the check variety, US-10, and approached that of opaque-2 corn.

UC-1 safflower, recently developed by Knowles, produces oil, called "oleic oil," with about 78% oleic acid and 15% linoleic, as compared with 78% linoleic and 14% oleic in oil of standard safflower varieties (3). The protein characteristics of UC-1 and standard safflower varieties are similar.

Breeders and pathologists have been especially concerned with developing disease-resistant varieties of safflower. Five breeding selections containing various genes for rust resistance were released in November 1969. A selection with resistance to verticillium and fusarium wilts was released in December 1969. A selection with resistance to phytophthora rot was released in August 1969.

High fiber content of safflower meal is still a problem. Thin hull types have lower fiber content than traditional types. The thin hull character has not yet appeared in any commercial varieties because of low yields.

Development of hybrids is making good progress, but evaluation is difficult. In recent work of D.D. Rubis of Arizona, the best hybrid yielded 42% more than the average of three check varieties, but only 11% more than a new variety, Rio (7). Oil percentage is higher also. The hybrid

TABLE II

Comparison of FAO Amino Acid Standard
With Amino Acid Distribution in Oilseed Crops[a,b]

Amino Acids	Relative FAO Standard	Soybean meal	Cottonseed flour	Safflower meal	Sunflower meal	Sesame meal
Leucine	4.8	8.5	6.9	6.2	7.6	8.6
Lysine	4.2	6.9	5.1	3.1	3.7	3.1
Valine	2.8	5.7	5.8	5.7	5.9	4.5
i-Leucine	4.2	5.9	4.4	4.0	5.5	4.9
Tyrosine	2.8	3.4	3.2	3.1	2.8	4.9
Phenylalanine	2.8	5.5	6.2	4.4	5.3	7.5
Threonine	3.3	4.3	4.2	3.3	3.9	3.7
Sulfur AA	3.4	3.4	3.5	3.3	4.1	5.8
Tryptophane	1.1	1.5	1.4	1.6	1.5	1.7

[a]Sources: Soybean, cottonseed, sunflower and sesame: "Yearbook of Agriculture, 1959"; safflower, Kohler (4); FAO Standards; "Protein Requirements" Report of FAO Committee, Rome, Italy, Oct. 1955; "FAO Nutritional Studies" 16 (1957) as adjusted (4).

[b]Per cent nitrogen.

which yielded the most oil per acre exceeded the average of the three check varieties by 51% and Rio by nearly 30%.

Crossing percentages in Rubis' study were 57% to 88%, resulting in hybrid production of 92% to 99%.

Some of the companies with active safflower breeding programs have been interested in developing hybrids. However, we do not know of any hybrid which has been released for commercial production.

Sunflower

Interest in production of sunflowers as an oilseed crop has increased substantially in recent years. The crop is well established as a bird seed and confection crop on about 100,000 acres in Minnesota and North Dakota. Total acreage exceeds 200,000. Different varieties are desired for oilseed purposes in order to obtain higher yields of oil.

Russian sunflower varieties have been used in the United States for oilseed production. Research has been limited and scattered. It has been concerned with increasing yield, oil percentage and uniformity.

Male sterile parental stocks for sunflower hybrids have been released. It is likely that American varieties will be hybrids. In the first generation of male sterile material, released in 1968, about half the plants were male fertile. The male fertility is necessary to maintain the line. Male fertile plants must be removed by hand before they shed an appreciable amount of pollen in crossing fields.

More recently cytoplasmic male sterility with a high degree of self incompatibility and with appropriate restorer genes has been discovered in sunflower. Manual roguing of these lines is unnecessary because there is only a negligible amount of self fertility. M.L. Kinman, leader of the USDA sunflower breeding program, predicts that female parents of commercial sunflower hybrids will be single cross hybrids involving a cytoplasmic male sterile line ("A" line) and a nonrestorer ("B" line) of similar agronomic traits. The resulting hybrid is male sterile but is maintained through the AxB cross. The commercial hybrid will result from a cross of this female parent with a restorer ("R" line) possessing dominant resistance to disease (2).

Protein has received little attention in sunflower. Although total protein production is small, less than 10% of the achene (i.e., the "seed" of commerce) or less than 100 lb of protein per acre at present average yield levels, the oil free meal may have 40% to 45% protein of good nutritional quality (Table III).

Panchenko and Dyakov of the USSR reported protein content of four varieties at the Sunflower Conference in 1968 (6). Protein percentages in the kernel varied from 12.5% to 15.1%, and in the achene from 8.3% to 9.3%. Unfortunately, lysine is the limiting amino acid (Table II).

A major limitation on farmer interest in sunflowers is their susceptibility to pests, especially the sunflower head moth, *Homoeosoma electellum*. There is not likely to be any substantial acreage of sunflowers in the south until the head moth is under control.

During the past summer there was extensive infection of sunflowers in the Red River Valley by downy mildew, *Plasmopara halstedii* (8). A large number of fields were affected and some were abandoned as not worth harvesting. We have dominant genetic resistance to downy mildew which should permit transfer of this trait to hybrids, but all present commercial varieties appear to be susceptible. Downy mildew, an obligate parasite, has developed many races in other crops as identified by the varieties they attack. Thus we may encounter considerable difficulty in developing and maintaining resistant varieties.

Sesame

Successful establishment of sesame as a crop in the United States will depend primarily on yield in mechanized agriculture. Oil percentage is high and the oil is of good quality and stability. The protein is deficient in lysine (Table II). Total research investment in sesame improvement in the United States or elsewhere has been small, and has been concerned with increasing yield.

Dehiscence or shattering is a major defect of sesame. A gene for indehiscence has been known since 1946. The gene has been disappointing because several deleterious characters, such as low yields and thick-walled, hard to thresh capsules, seem to be associated with indehiscence. "Partly shattering" lines are being evaluated in California by D.M. Yermanos, University of California, Riverside.

Research on oil and protein quality, and on disease resistance, has been limited and is now practically nonexistent. We know of no breeding work related to oxalic acid in sesame. Breeders have thought that oxalic acid is not a serious problem because about two thirds of it is in the seedcoat, which is removed in decortication.

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