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7TH RESEARCH CONFERENCE ON DRY BEANS

Held December 2-4, 1964 at Ithaca and Geneva, New York

AGRICULTURAL RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

THE SEVENTH DRY BEAN RESEARCH CONFERENCE was held December 2-4, 1964, in Ithaca and Geneva, New York. It was attended by bean growers, shippers, and processors from various growing areas and by research and extension workers from State and Federal agencies. Its purpose was to present results of current research and development pertaining to the production, marketing, and utilization of dry beans and to afford an opportunity for exchange of information and discussion of problems. A special feature was a symposium on bean root rot on December 2, immediately preceding the formal opening of the conference on December 3. Sessions were held at Geneva on the final day.

Sponsors of the conference were the National Dry Bean Council, the U.S. Department of Agriculture, and State Agricultural Experiment Stations. Hosts were Cornell University at Ithaca and the New York State Agricultural Experiment Station at Geneva.

James O. Cole, Canandaigua, New York, served as General Chairman. Irvin C. Feustel, Federal Extension Service, USDA, Albany, California, and D. H. Wallace, Department of Plant Breeding, Cornell University, Ithaca, New York, were Program Co-chairmen. The advice and assistance of M. J. Copley, Director, Western Utilization Research and Development Division, Agricultural Research Service, USDA, Albany, California; William A. McCormack, President, National Dry Bean Council, San Francisco, California; and Gordon W. Monfort, Manager-Assistant Secretary, California Lima Bean Advisory Board, Dinuba, California, are gratefully acknowledged.

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July 1965.

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RESEARCH CONFERENCE ON DRY BEANS

INTRODUCTORY REMARKS

William A. McCormack
The Trinidad Bean & Elevator Company, San Francisco, California

It is my privilege as President of the National Dry Bean Council to welcome you today on behalf of the entire bean industry. I am fortunate in being called upon to extend a welcome to a group which is 100% receptive, unlike that of another organization of which I've heard--Local 1642, which sent a telegram to a sick member, stating that the Local wished him a speedy recovery by a vote of 49 to 38.

In looking through the room I recognize people who were here 6 years ago and I'm sure they will have observed the great amount of knowledge concerning beans which has been uncovered since that meeting. We are about to hear of present developments from many people from all over the country. Some of the developments are of particular interest to scientists and others to the layman. Some are international in scope and others deal with micro-organisms, but all are directed to the objective of progress and improvement for the industry, and by this I mean the grower, processor, shipper, canner, and packager. The wooing of the ultimate consumer is not being overlooked either.

The welfare of all is at stake in this research program. Competition of foods with new products being developed weekly calls for action on our part to stay up with the parade or fall by the wayside. We are all aware of this and there's no need to go into detail. Our future is in this program.

May I take this opportunity to thank Dr. Wallace and Dr. Feustel, who have handled the arrangements, and Jim Cole in acting as General Chairman of the meeting for the bean council. Would also like to particularly thank Dr. Mike Copley of the USDA at Albany, California for his continued interest in our programs and his continuing cooperation. All these people have done a great deal for the dried bean industry, and we are indebted to many others, those who are presenting papers of their works at this meeting and those at home who are backing up the work. Again, a hearty welcome and may this meeting be most productive.

PRINCIPLES OF AGRICULTURAL RESEARCH IN THE UNITED STATES

(Condensation of talk by Nyle C. Brady, Director of Science and Education, USDA, presented by Sam R. Hoover, USDA)

Publicly supported agricultural research in the United States had its major beginnings in 1862, following enactment of two Federal laws creating the Department of Agriculture and the land-grant colleges. Legislation in 1887 made Federal funds available to States on a continuing basis, to establish and operate agricultural experiment stations as part of the land-grant colleges. In 1914, legislation was enacted to set up a cooperative Federal-State agricultural extension service to bring new research ideas and techniques to people on the farms. Thus was established the legislative framework for our Federal-State system of agricultural research.

In the broad sense, our agricultural research also includes the increasing research being conducted by farmer organizations, by private foundations, and by many food and farm-related industries. These groups have made and are continuing to make important contributions. To understand the overall structure of agricultural research, we will begin with the Federal organization. Three important organizations have been created recently in the Executive Branch of our Government, to cope with increasingly sophisticated problems in science communication, management, long-range planning, policy making, and allocation of resources and personnel. Each has well-defined responsibilities.

The Office of Science and Technology is a permanent staff unit which assists the President in developing policies and evaluating programs to make sure that science and technology are being used most effectively. The President's Science Advisory Committee is composed of outstanding scientists from universities, industry, and private organizations to advise him on the role of the Federal Government in furthering science. It undertakes special studies designated by the President and initiates many of its own, some in agriculture. The Federal Council of Science and Technology, composed of representatives of the eight Government agencies conducting research, is concerned with more effective planning and administration of Federal scientific and technological programs. The Council's membership includes the Departments of Defense; Health, Education, and Welfare; Interior; Commerce; and Agriculture; and the National Science Foundation, Atomic Energy Commission, and the National Aeronautics and Space Administration.

The United States Government is spending about $15 billion this year to support the research of these agencies. Less than 1-1/2% of this budget is expended for agricultural research. This is a substantial drop from 1940, when agriculture received some 40% of the $74.1 million the Federal Government was spending for research. In dollars, Federal expenditures have increased from $74 million in 1940 to $186 million in 1964, not much more than the increased cost of doing research.

As I have indicated, agricultural research in the US is a joint effort of public and private agencies. The public partners--the Department of Agriculture and the State agricultural experiment stations--are spending approximately $326 million. This includes $10 million transferred to the Department this year from other Department agencies for specific work. Out best estimate of what private industry spends is approximately $400 million. Industry has become a major force in agricultural research in the last few decades--because of the machinery, chemicals, and biologicals that industry supplies to agriculture, and because of the raw materials that agriculture provides to industry.

Now, let's examine the public funds of $326 million for agricultural research a little more closely. The $140 million that the States provide includes $7 million made available by industry for agricultural research. The Federal Government provides $143 million for the Department of Agriculture and $43 million for Federal grants to the States. Part of these Federal-grant funds, by the way, are distributed equally to each State, and the rest in accordance with a formula based on the State's rural and farm population. Incidentally, these figures represent the operating budget and do not include funds for facilities. Thus Federal appropriations allocated to the Department of Agriculture comprise the major source of money for agricultural research, with Federal grants to the States an important part of these appropriations. State appropriations going to the State experiment stations are the second largest source of funds for agricultural research.

Money also comes from Federal agencies other than the Department through contracts and grants; from industry and private sources, through grants and fellowships; and from various research agencies of the Department through contracts, cooperative agreements, and grants. Funds for the State experiment stations total $213 million, of which $140 million are State appropriations and industry funds, $43 million are the Federal grant funds previously referred to, $24 million are from other Federal agencies, and $6.3 million are derived from USDA research contracts.

Now I want to talk about how we plan, manage, and coordinate research. . . and the organization through which research operates. There are five major agencies with research functions within the Department of Agriculture: the Agricultural Research Service, Forest Service, Economic Research Service, Farmer Cooperative Service, and the Statistical Reporting Service. In addition there is the Cooperative State Research Service. This is the agency within the Department that administers the Federal-grant funds to the State experiment stations. The Federal-grant funds support about a fourth of the research of the State stations, with the States, industry, and foundations providing the rest.

The Director of Science and Education is directly responsible for only the Agricultural Research Service and the Cooperative State Research Service. Other research is, however, fully coordinated through the Director's office. In coordinating research, we have the help of the administrators of the various agencies and the assistance of committees and groups, both in and outside the Government. Each committee or group has responsibilities for order and direction in a large and complex establishment. They help us to determine if we are doing a good job . . . and if we are making adequate plans.

To begin with, internal review is carried out through the newly formed Research Program Development and Evaluation Staff. This organization has major responsibilities for assistance in the development of the Department's research programs. It will coordinate research activities among Department agencies and with State, private, and other research organizations. . .and it will carry on a continuing evaluation of research to determine if goals and needs are being met.

The new staff will have the assistance of various program work groups to conduct whatever detailed, specialized studies are necessary. External review and advice come from several sources. One is the Committee on Agricultural Science, composed of 15 outstanding scientists. This Committee continuously evaluates research supported by Federal funds, particularly work of a basic nature. Review panels assist in planning and maintaining cooperation between agencies of the Department and research in related fields. Next, we have the National Agricultural Research Advisory Committee, established by the RM Act of 1946, whose members are concerned with various aspects of agriculture. This committee makes recommendations to insure broad coverage of important areas. It also maintains contact with 12 advisory or commodity committees, which review segments of current research and recommend adjustments. These unique committees offer an ideal system of communication between the Department and consumers and farmers.

Now let us go to coordination of Federal and State research. The recently established Agricultural Research Planning Committee will provide a strong base for coordinating the programs of all agencies. This group will assist in working out long-range national plans and goals and in determining the areas of Federal and State responsibility. Other responsibilities include improving Federal and State cooperation in broad regional research, helping coordinate plans for Federal and State facilities, and stimulating interchange of scientists at all levels. Membership includes representatives of Department research agencies; Station directors selected by the Experiment Station Committee on Organization and Policy; a president of a land-grand university, selected by the Association of State Universities and Land-Grant Colleges; and representatives from the National Academy of Sciences and the Office of Science and Technology.

Coordination is achieved also through maintaining and using up-to-date inventories of all current projects. This project system, which we are in the process of modernizing, helps us in examining and analyzing all current and proposed Federal and State research. Currently, the Department maintains records of some 3,700 USDA projects. The Cooperative State Research Service maintains similar records on approximately 6,700 State-supported projects, and 6,400 projects financed all or in part by Federal funds. Both sets of records provide background against which all proposed new projects to be supported by Federal funds are examined. This is the key to effective coordination and prevention of unnecessary duplication.

According to current plans, we expect to have the records of the State-supported projects, Department projects, and Federal-grant projects fully automated, and in one place. This will involve extensive voluntary cooperation on the part of the experiment stations in providing information on State-supported projects over which the Department exercises no control. The improved system for maintaining project records will provide a source of communication between scientists on all aspects of current programs. And it will provide comprehensive information to permit ready analysis of research for more effective management.

To summarize--publicly supported agricultural research in the United States is carried on jointly by the Department of Agriculture and the autonomous State land-grant universities, each with its college of agriculture and experiment station. Farm and industry organizations and other groups assist in planning and financing. Although our public agricultural research involves Federal and State action and wide dispersal of activities, the important thing is that it is essentially cooperative, directed to a single national purpose--the most efficient production, processing, marketing, and distribution of our farm products. And it takes into account the varying conditions and needs of the States.

If, as someone has said, culture is wine and cheese, and civilization is bathrooms and plumbing, I say it is the task of agriculture to provide the kind of abundant economy that will make both possible.

OUTLOOK FOR DRY BEANS

Gordon Monfort
California Lima Bean Advisory Board, Dinuba, California

Most of the information and even some of the crystal-gazing you will hear from me has been supplied by leading authorities in each of the nation's major bean-producing areas. Their thoughts have been collected on a questionnaire mailed about 60 days ago. Hence the guesses are not only informed or educated guesses, they are current. Another procedure of experienced forecasters is to look at the past for a clue to the future. This was done with the help of USDA's agencies, ASC, ERS, AES, FAS and ARS. Through their retrospective eyes I looked at production trends (by area and by variety), prices paid to growers, disposition of past supplies, and effect of price support activities.

To digress just a moment, "Statistical Summary of Dry Edible Beans and Dry Field Peas," dated October, 1964, and published by Federal Extension Service, is recommended reading for anyone interested in the history of our industry. Finally, with the help of bean dealers, association officers, board members, and others closely associated with the industry, I selected the factors which seemed most influential in the past and most likely to affect production, price trends, and consumption. At this point in my study, a pattern began to appear. In fact, the US dry bean industry is involved, like many another American family, in a complex "eternal triangle." The bean industry's triangle is economic, pointed toward profits at one apex and deriving its lifeblood from production and consumption at the other two.

To illustrate, I have drawn a rather crude, but I think significant chart showing the complexity of the problems facing the industry and how intertwined are the factors that have a bearing on outlook. Now, let's look at the key factors and see if we can predict production, price and consumption of dry beans.

PRODUCTION
OF
DRY BEANS

CONSUMPTION
OF
DRY BEANS

PRODUCTIVITY

SEED - Resistance
- Yield
- Adaptability

PHYSICAL FACTORS:
Labor Supply
Mechanization
Water Supply
Weather
Cultural Practices

HUMAN FACTORS:
Quality and support of personnel working on bean problems.

ACCEPTABILITY

PRODUCT IMPROVEMENT:
Better appearance, flavor, nutritive value, palatability, digestibility and convenience. New uses, recipes and combinations.

GOVERNMENT ACTIVITY:
Welfare purchases, price supports, trade policies.

MARKET RESEARCH:
Locate new customers and find best ways to sell them. Increase consumption by present users.

PROMOTION:
Plan now for future sales growth.

PROFITABLE
SALES OF
DRY BEANS

At the moment most of you are engaged in the all-out effort to improve dry bean seed, cultural practices, and field handling methods. The industry is to be complimented for inaugurating research in every locality and phase of bean production, and the National Dry Bean Council is certainly to be commended for coordinating and accelerating our research effort. Though we are examining the national outlook, the economy of the industry is so interrelated we must study regional problems and the imminence of their solution to predict what is likely to happen nationally. Let's start with California. Although second to Michigan in total production, its volume covers many varieties also grown in other localities and what happens to California beans is likely to have direct effect on other regions.

CALIFORNIA: Pinto, Cranberry and Small Red--These losing out. Cranberry is late for California conditions. Pintos and Cranberries bring lower returns to growers than alternate crops. Hence, not much increase expected for these varieties. Will do well to hold own.

Pinks--Have been driven out by root rot. However, a University of California program has developed a resistant variety which should begin to restore production to normal in the Salinas area by 1970. Long-range growth of production depends on interior valley production. Fusarium is a problem there, but resistance is on the way, though no release date yet set. Rhizoctonia is also a problem with no resistant strains yet found.

Small Whites--Suffer from mosaic susceptibility. Should increase from here on with new resistant strain. Flat whites are expected to increase. They do better in interior valleys than small whites.

Dark Red Kidney--Represents 40% of red kidney acreage at present due to University of California Experiment Station developed variety that outyields Michigan variety in California. Has been inferior for canning because of splits, but new selection to be released soon compares with Michigan's as a canner; is expected to boost acreage.

Blackeyes--Extremely cyclic. Has no major problems except violent fluctuations in volume and price brought on by cycles of over and underplanting. My correspondent sees little hope of changing human nature on this score.

Large Limas--Production has declined steadily. This trend expected to be reversed soon by varietal improvement work at University of California promoted and subsidized in part by the Lima Bean Advisory Board. Goals are uniformly white seed coat for export and canner market, nematode and disease resistance for higher yields, and heat resistance to maintain quality when grown in interior valleys. This is a must as houses gobble up coastal areas. Papers presented later on this program will tell how and when these goals will be achieved.

California summary--Competition with people for good lands will result in growers coming out second best. Acreage declines will about offset increased productivity per acre from cultural improvements, but more of the land remaining in agriculture is expected to find its way into beans because high labor costs and lack of workers will make mechanized beans attractive to more growers. Net result should be overall increase in production of 10 to 12% by 1975.

IDAHO: Pintos--Expect decline of 15% by 1970 due to greater grower returns from other varieties.

Great Northern--Predict 10% increase by 1970 from better strains which have upped yields and provide earlier maturity.

Small Reds--Expect 10% increase by 1970 from new strains adapted to better growing areas with short growing seasons.

Red Kidney--No change expected.

Idaho summary--Little overall change in total production. Idaho correspondents say incentive for increased production must come from increased returns to growers brought about by consumer demand for a quicker cooking product and new uses for beans.

COLORADO: Pintos--Idaho 111, no change in volume expected. Is a good bean for the state and readily marketable. San Juan Select not expected to change. Will continue to be grown in southern areas adapted to nonirrigation. Scout, a rust-resistant variety not expected to increase because small size is meeting market resistance.

Colorado summary--Some small expansion in production may be expected in newly developed pump-irrigation areas.

MICHIGAN: Pea (Navy)--Gradual increase in production expected to meet growing popularity of canned product in US and abroad.

Red Kidney--Increase expected due to high interest in certain growing areas.

Pinto--No change since variety not well adapted to Michigan.

Cranberry--Decline expected due to waning interest by buyers, hence by growers.

Michigan summary--Production will gradually increase, say Michigan correspondents, as we learn to promote demand and produce increased yields. Expect to be able to market expanded volume profitably.

NEW YORK: Red Kidney--Little change expected. Increased sugar beet allotments should reduce acreage just about enough to offset increased yields and declining attractiveness of some alternate crops.

Black Turtle Soup--No prediction ventured. "Depends on export trade with Venezuela. Has great domestic potential which is being overlooked," says New York correspondent.

New York summary--Production volume depends on support programs and ability of industry to develop markets. Ability to produce is almost unlimited if demand supplies the incentive to plant.

Summary for US production. The only localities where important increases can be expected are in Michigan and California. Other areas expected to range from no change to slightly down. All agree production capacity is there if demand returns sufficient profit for growers to plant in preference to alternate crops.

Price. This is perhaps the most dangerous area in which to predict. Price is the end product of both production and consumption and is influenced by many other factors as well: price supports, government purchases, welfare handouts, general economic conditions, promotion effort, supplies of other foods, and even politics. Little wonder few correspondents would venture into the quicksands of price prediction. Those who would discuss the subject at all agreed on three points: (1) Short range price trends will remain unchanged. (2) The long range trend will be slightly down. (3) How much prices will go down depends on extent of price supports and how well we learn to sell our products. These three predictions are qualified by the assumption that yields will be increased enough to offset generally lower prices.

Since price supports play such an important part, thus affecting both grower profit and consumption, let's see how much of our crop has been placed under loan and actually delivered during the five years since 1959. As the following table shows only a small part of the total crop is affected, but the level of support and the mere presence of the support program exert an artificial influence over the price structure of all dry beans.

PERCENTAGE OF TOTAL CROP UNDER SUPPORTS:

Area	% placed	% delivered
US as whole	17.0	8.0
California	2.6	Less than 0.5
Colorado	16.0	6.0
Idaho	8.0	Less than 0.5
Michigan	20.0	11.0
New York	8.0	5.0

This is no place to engage in a discussion of the pros and cons of price supports. It is well to keep in mind, however, that there are advantages and disadvantages as far as the industry is concerned. Obviously, supports encourage overproduction, but they provide a floor under prices. Some economists contend the floor under prices restricts price cycles and tends to hold down peaks. However you may feel about price supports on dry beans, you will agree that there are only two ways to eliminate them: kill them by political pressure or build up consumption to move all we can grow into open markets at world price levels. Of the two courses, the latter appears just as possible and certainly more desirable. Finally, let's look at the real key to the growth and stability of the dry bean industry.

Production. Obviously, we have ultimately been able to dispose of what we have produced in one way or another, BUT not without subsidy and not without substantial periodic grower losses. The future, in my opinion and that of my correspondents, lies in volume production sold at a profit. To achieve this goal we must overcome many remaining obstacles. We should begin now to coordinate an industry-wide attack on remaining obstacles to expanded sales at profitable prices. Our chart shows the direction this attack should take, as follows:

1. We must expand and accelerate our product improvement research with these objectives, some old, some modified, some new: Productivity per acre: so we that can sell profitably at prices more competitive to other foods. We have an advantage here. Let's expand it. Quality: appearance, flavor, nutritive value, palatability, digestibility, and convenience can and must be improved to make our product competitive with other foods. Necessary not only for more profit, but for survival. New ideas for beans: new uses, new recipes, new food combinations. This is a field where private industry can shine. Home economists must develop exciting new bean dishes to tempt homemakers, institutional meal planners, and government feeding agencies. A possible approach: develop greater use of beans as vegetable accompaniment as well as a substitute for meats.

2. We need careful study by industry and government in three important fields: The effect on prices of government purchases for relief. The total effect of price supports and what changes, if any, should be made in present policy. What foreign trade policies the industry should advocate as they involve: tariffs, food-for-peace, government sales abroad, PL 480 programs. Approach should be: Can what we have be improved?

3. We need to develop a program of market research--by private, university and government groups under the guidance of the Dry Bean Council--to learn what we can do to sell more beans at profitable prices. Fields to explore: Possible expanded use by institutions (USDA and food industry are now developing a general institutional food study which should include dry beans). Use of beans to raise diet standards in underfed nations. Better use of by-products. Opportunity for increased sales in foreign markets. Ultimate effect of population explosion on bean consumption. Using improved communications and shift of population centers to spread bean-eating habits of certain nationalities to non-eating groups. How to break down the psychological barrier which classes beans as "poor-folks' fare."

4. We must begin now to promote beans as a low-cost diet essential for growing young bodies as an aid in developing physical fitness. Thought should be given to developing this as a national "sales theme" for dry beans.

These are just a few of the things waiting to be done. But they will not get done as fast as we need if we don't take specific, positive steps. May I propose that the activities of this group here can be further coordinated, somewhat expanded, and brought into sharper focus by expanding the Dry Bean

Research Committee of the Dry Bean Council. I suggest the formation of three subcommittees: Product Improvement, Government Relations, and Market Development. The main committee would continue to direct and coordinate work in all three fields, guiding the subcommittees whose duties should include: (1) studying their respective areas of research to select projects most needed, (2) lauching needed projects and pressing for support when funds or personnel are needed, and (3) acting as a coordinating body for research workers.

I wish I could give credit to those who assisted me, but I promised anonymity. If you like what you have heard give credit to an industry-wide effort. If you don't like it, blame me for opening up the whole Pandora's box of troubles.

A final word: there is no doubt that the future will provide all the opportunity, all the incentive, all the reasons we need to achieve these goals. Human demand for the high-value, low-cost food offered by dry beans cannot help but grow. Our outlook is as bright as we have the courage, foresight, and wisdom to make it. If we step out to meet the challenges laid down by my correspondents, we will prosper. If we wait for time and circumstances to save us, we will be put out of business by the producers and handlers of other foods who will not be waiting.

FACTORS AFFECTING PRICES OF DRY BEANS

R. Brian How
Cornell University, Ithaca, New York

(This paper reports the results of work initiated while the author was on leave from Cornell University employed by the Marketing Economics Division, Economic Research Service, U. S. Department of Agriculture, Berkeley, California.)

Production of dry edible beans in the US in recent years has averaged 18.5 million hundredweight, with a farm value of $135 million. Commercial production of 16 separate classes or varieties is reported annually for 12 states ranging from New York to California and Montana to New Mexico. Some states, such as Colorado, tend to specialize in a single class while others such as New York grow many types. A few classes account for the major share of total production.

Short total crops of dry beans in 1946 and 1947 brought high prices which were reversed by large crops in 1948 and 1949. These crops were followed by an upward trend in total US production, due primarily to increasing yields, since acreage has remained stable since about 1950. In recent years production has varied widely. Production of some classes, such as Pea beans, has increased substantially while that of others, for example Limas, has decreased.

Total US exports, both commercial and government assisted, have shown no definite trend while ranging from about 10 to 20% of annual production. Carryover stocks were relatively low at the end of the 1962 season. During the 1948-62 period an increasing quantity of dry edible beans was moved into the domestic market either by commercial sales or through publicly assisted distribution programs. Increased production was accompanied by a downward drift in average prices. Government price support and distribution activities have been a major factor during the postwar period. During 1961 and 1962 about 2 million hundredweight of dry beans, or 10% of each crop, were exported or distributed domestically under government financed programs. From a high in 1952 and 1953 the national support rate for dry beans was cut substantially by 1959. The relative level of support for individual classes in specific locations has also been changed. Among others the support rate for Pintos and Baby Limas has been reduced relative to the national average, while the rate for Pea beans has been maintained.

Limited published information is available on the season average farm or wholesale prices of specific classes of beans. The USDA however maintains a series of seasonal average f.o.b. prices for major classes in major producing areas. Information on prices of California varieties is obtained by the Market News Service in California. The season average prices are simple averages of monthly prices rather than averages weighted by sales. The farm price of Red Kidneys is estimated monthly by the New York Crop Reporting Service.

Factors influencing prices. Major factors affect dry bean prices, but there is increasing evidence that each class should be considered a separate commodity. Both supply and demand conditions tend to differ among classes. Factors affecting annual average prices of classes are as numerous and their interrelationships as complex as for any major agricultural product. Each major class of beans can be stored, has several close substitutes, can be sold for different uses, is subject (with one exception) to government price support and public distribution programs, may be exported or sold in competition with imports. The limited quantity and accuracy of available data unfortunately limit the depth of analysis that can be performed.

Analyses of price changes. Five classes of dry edible beans--Red Kidney, Pea, Pinto, Large Lima, and Blackeye--account together for about three-quarters of total US production. Analyses of factors affecting changes in annual average prices were made for each of these classes. Single-equation least-squares multiple-regression analysis was used to investigate the relationships between price changes and various economic factors. Under certain conditions this method can provide useful insight into relationship between economic variables and the usefulness of the equation for prediction. The coefficients of the independent variables, along with their standard errors, indicate the nature of the association. The coefficient of multiple determination, symbolized as "R^2," indicates the proportion of variation in the dependent variable associated with corresponding variation in the independent variables. The statistic "d" indicates the degree of serial correlation in the residuals, or the appropriateness of the model for the particular data.

Unfortunately for the first four of these dry bean classes it was not possible with available data to develop single equations or systems of equations that appeared to identify the true structural relationships between various factors. Government activity and export markets make complex interactions difficult to separate. For these four classes the price equations that were developed are likely to be useful only in general predictive sense and should not be used to determine the relationship between specific factors and price. These equations and their evaluation are available on request by anyone who is especially interested.

In the case of Blackeye beans, greater success was apparently achieved in identifying structural relations between various factors and production, annual price, and carryover stocks. Equations expressing relationships between such factors and these three variables form a model which it was possible to use to simulate the behavior of the market over a period of years.

Blackeyes. There is difference of opinion whether Blackeyes should be classified as beans or peas. In the South Blackeye peas are generally eaten fresh, although some are ultimately harvested and distributed in dry form. The same plant is grown in the West for production of the dried product. California is the only state for which production of dry Blackeye beans is reported, although Texas also produces a substantial quantity for commercial sale.

Blackeye beans have not been eligible for government price supports. Production and prices have varied widely during the 1948-62 period. Prices showed a sharp downward trend particularly from 1950 to 1955. Changes in production from year to year have been primarily the result of changes in acreage, although occasionally a year of generally low yields has occurred. There is apparently a fairly specific domestic market for Blackeyes, which does not overlap with any other major dry bean class. There is apparently no substantial foreign trade in this class.

Because of the lack of government operations, competition from other classes, and export trade the price analyses have been more successful than for other classes. It appears possible to identify the effect of several factors influencing production and prices and to measure these effects with a relatively high degree of accuracy. Blackeyes present an interesting contrast to Large Limas in this respect and others.

Production of Blackeyes appears closely related to price the previous year, production the previous year, and size of the carryover stock. Changes in production have been mainly due to changes in acreage harvested. An equation expressing the relationship for the 1948 to 1962 period is as follows:

$$Q_t = .240 + \underset{(.0083)}{.0136}\ P_{t-1} + \underset{(.265)}{.499}\ Q_{t-1} - \underset{(.650)}{1.843}\ C_{t-1} \qquad \begin{array}{l} R^2 = .78 \\ d = 1.36 \end{array}$$

In this equation Q_t represents production per capita in the given year, P_{t-1} the average price of Blackeye beans the previous year, Q_{t-1} the production the previous year, and C_{t-1} the carryover stock from the previous year. Production and carryover were measured in per capita terms, not because Blackeye beans receive national distribution but because growth in US population is the best indicator of the growth in size of the Blackeye market.

About 78% of the variation in annual per capita production was associated with corresponding variation in price the previous year and carryover stocks. Larger carryover stocks were associated with reduced production and higher prices with increased production the following year. Production calculated on the basis of this relationship followed actual production closely (Figure 1). Growers appear to have based their price expectations on previous prices with a distributed lag effect.

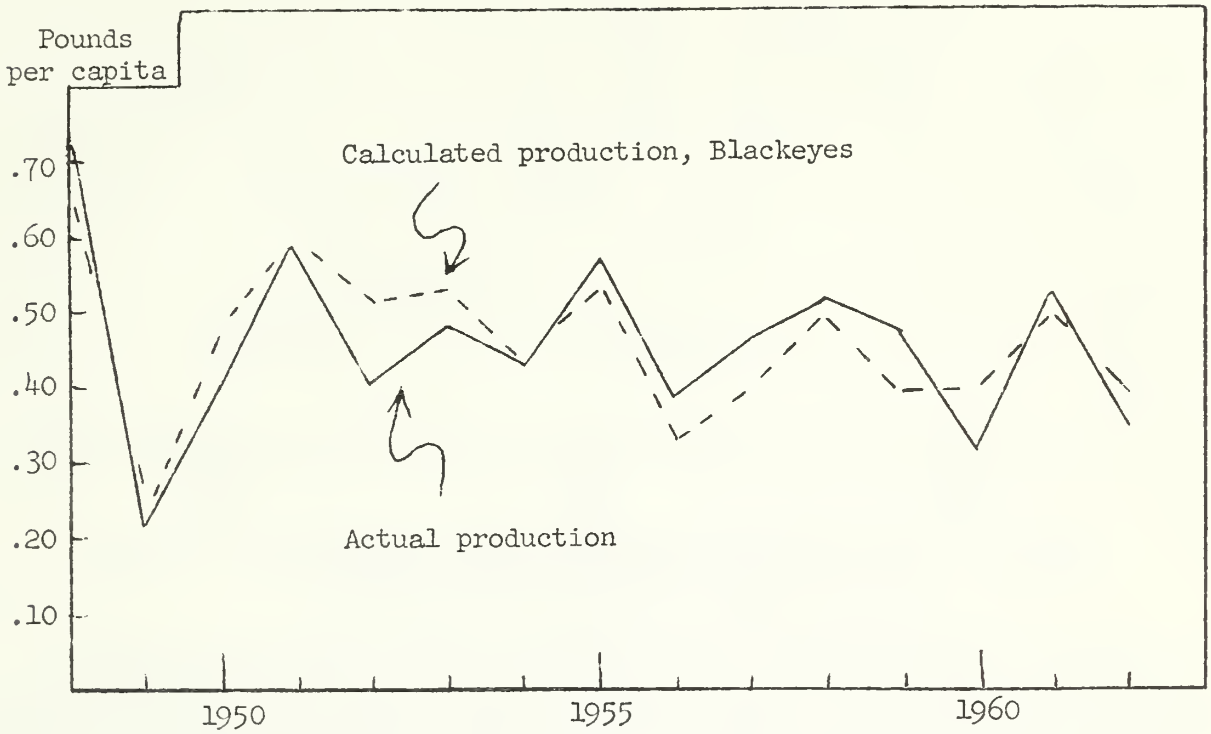

Figure 1. Production per capita of Blackeyes in California and production calculated from regression relationship.

No other class of beans apparently competed closely with Blackeye beans in the market place. The price of Blackeye beans during the period 1948-62 was closely related to production and carryover stocks of this class, and time trend. An equation expressing this relationship is as follows:

$$P_t = 27.062 - \underset{(3.009)}{27.347}\ Q_t - \underset{(5.863)}{30.941}\ C_{t-1} - \underset{(.052)}{.355}\ T \qquad R^2 = .91 \quad d = 2.89$$

In this equation P_t represents the average price of Blackeyes in the given year, Q_t the production per capita that year, C_{t-1} the carryover per capita from the previous year, and T the trend in time. Both carryover and current production had about the same inverse relationship with price. Trend factors have also had a negative relationship with price. Prices calculated on the basis of this relationship have followed actual prices closely (Figure 2).

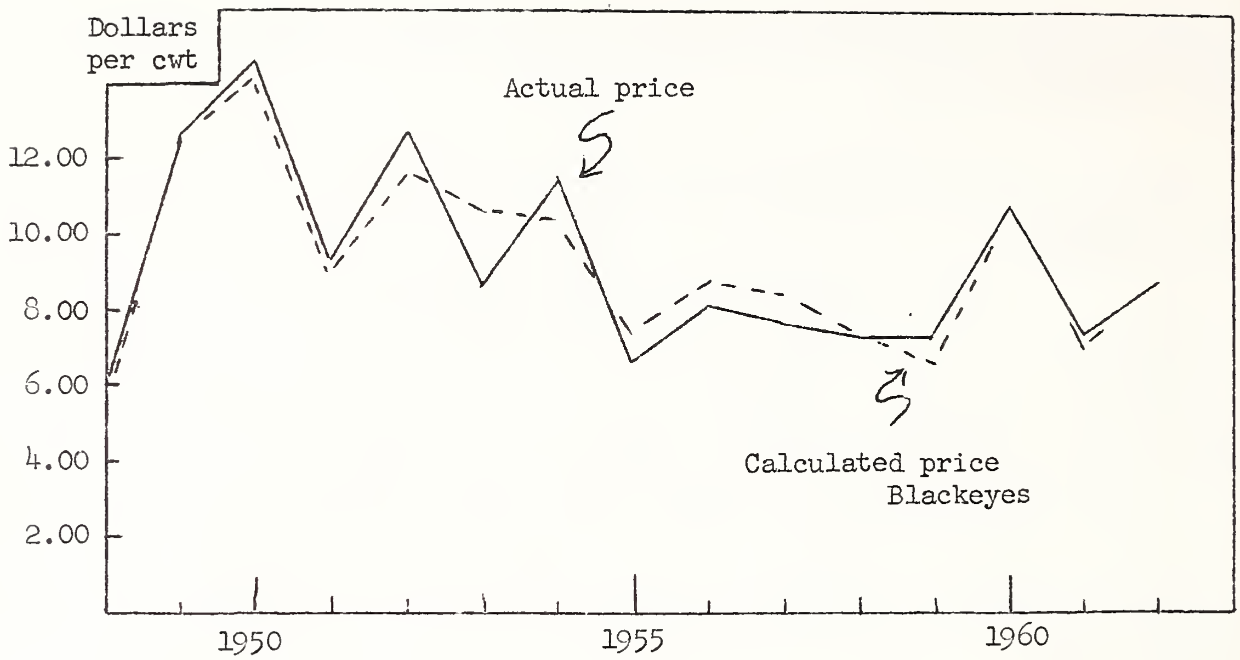

Figure 2. F.o.b. price of Blackeye beans, California, and price calculated from regression relationship.

Since carryover stocks have a significant association with production and prices the following year it is important to know factors related to changes in this variable. Current production and previous year's carryover had the closest association with year-end carryover during the period 1948 to 1962. The effect of price on carryover was either negligible or difficult to detect. A small upward trend in time was not signifeicent in a statistical sense. The equation expressing this relationship was as follows:

$$C_t = -.290 + \underset{(.092)}{.686}\ Q_t + \underset{(.179)}{.632}\ C_{t-1} + \underset{(.0016)}{.0013}\ T \qquad \begin{array}{l} R^2 = .87 \\ d = 2.07 \end{array}$$

In this equation C_t represents carryover stocks per capita at the end of the period, Q_t current production, C_{t-1} the carryover from the previous year, and T the time trend. Within the range of experience about two-thirds of additional supply was carried over to the next season. Calculated stocks mirrored actual stocks fairly closely, with the exception of carryover at the end of 1951 (Figure 3).

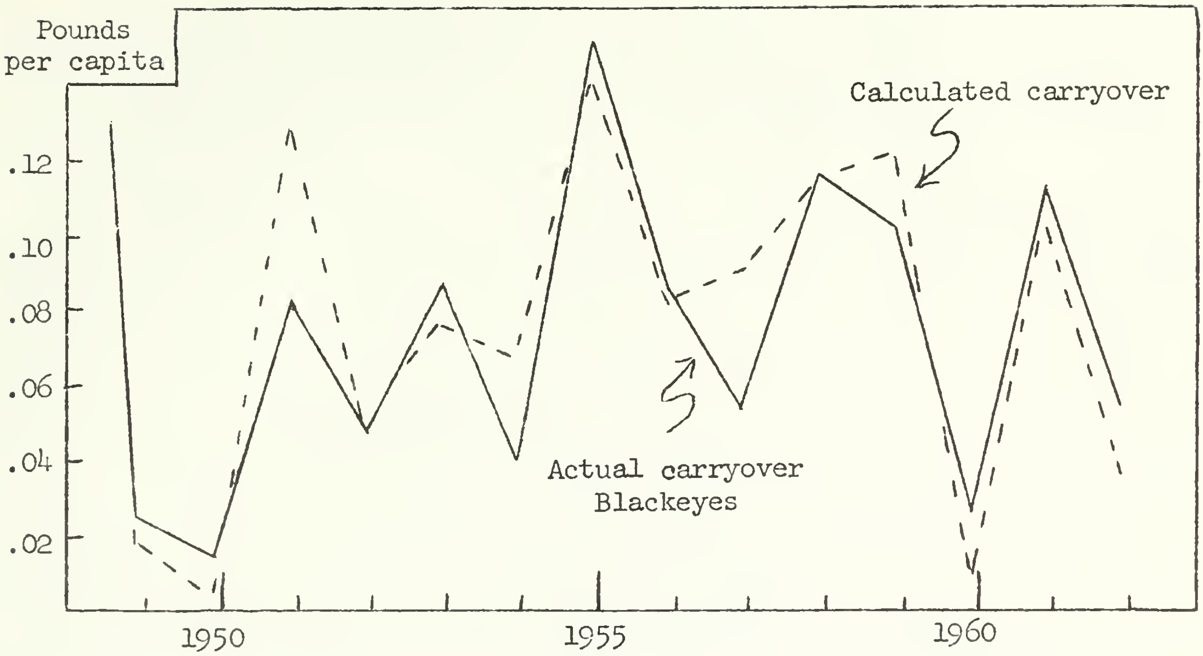

Figure 3. Carryover per capita of Blackeye beans and carryover calculated from regression relationship.

It may be tempting but would be dangerous to use this set of equations to predict prices a season in advance. For example, 1962 actual prices and carryover stocks indicated a 1963 production somewhat larger than average, which in turn would suggest a season average price of about $7.25 for the 1963 season. In actual fact poor growing conditions and unfavorable weather at harvest reduced both quality and quantity so that the season average price for US No. 1 Blackeye beans averaged $10.67. Unless conditions change, however, the relationships may hold in general for the next few years.

To study these relationships further a program based on this simple three-equation model was written for the Cornell computer that would find successive values for production, price, and carryover stocks. The program assumed that dependent variables in each of the three equations were subjected to disturbances that were random in nature, normally distributed, with zero mean and with variance equal to the variance of the original data unexplained by the fitted equation. This simulation model was started with average rates of production per capita, prices, and carryover per capita for the period 1948-62 and run for 50 years. This took about 10 seconds of computer time. For the first 20 years the path traced out by production and price were very similar in general to the actual experiences of the 1948 to 1962 periods (Figures 4 and 5). Simulated prices ranged from $3.92 to $13.54, and production per capita from 0.26 to 0.65 pound. Prices followed a definite downward trend especially toward the end of the period, while production per capita tended to level out at just over 0.4 pound per capita. This is equivalent to about 800,000 bags at the present population level.

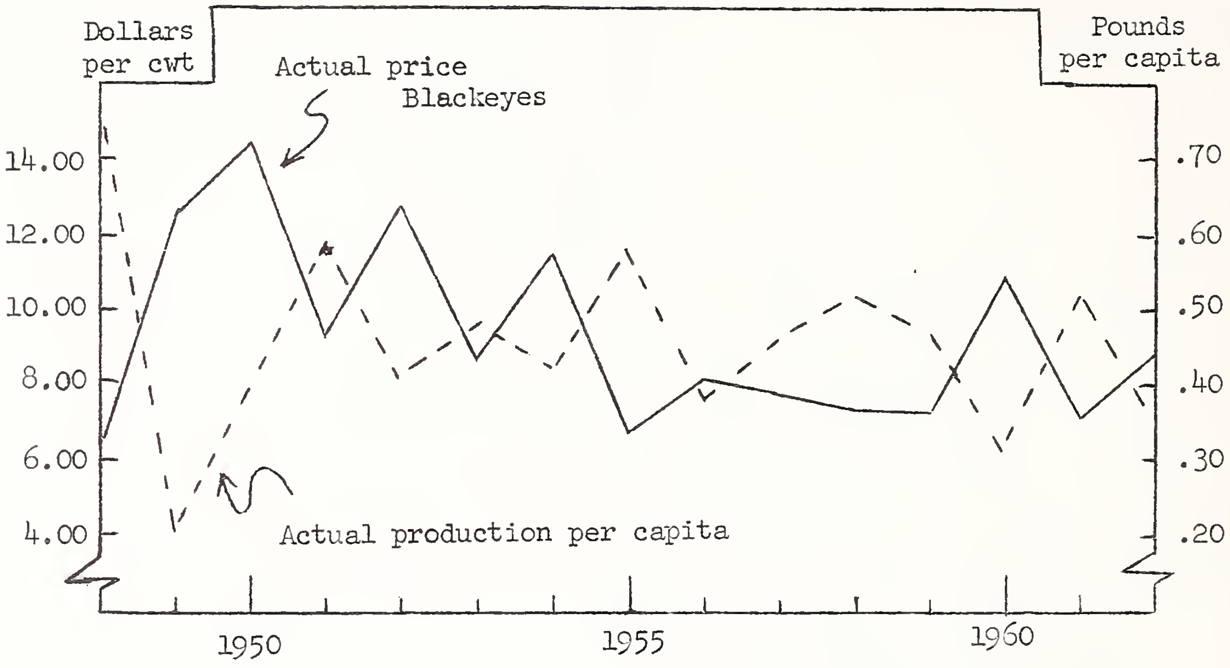

Figure 4. Blackeye bean actual price and production per capita, California.

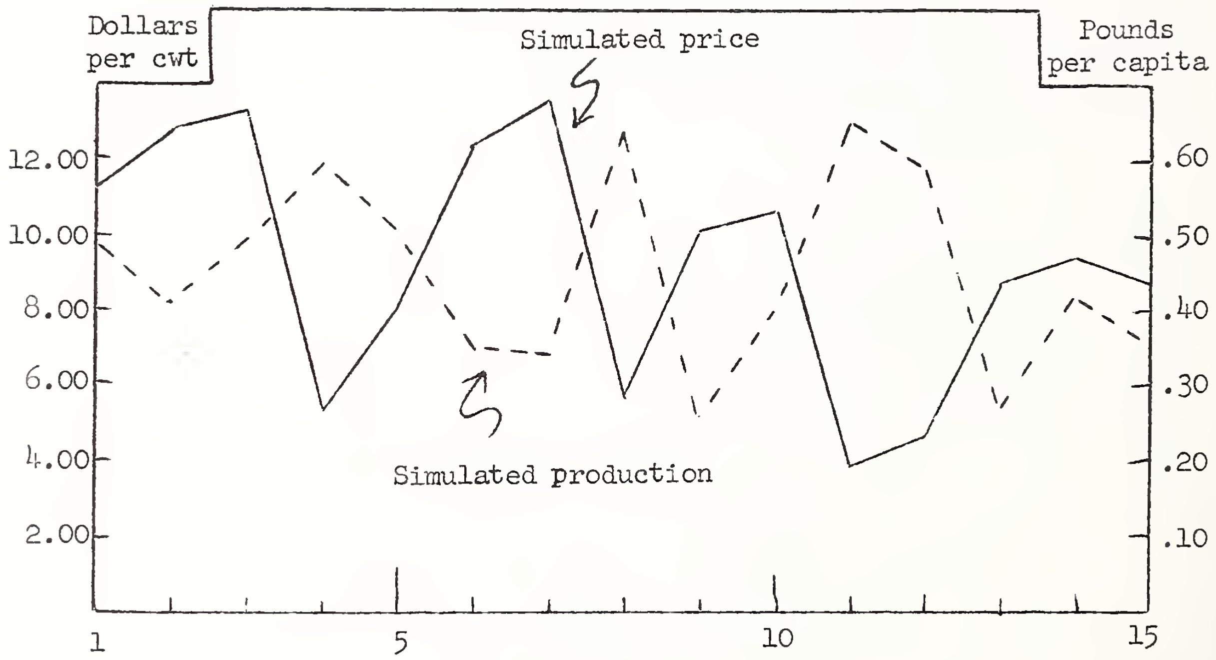

Figure 5. Blackeye bean price and production simulated by three equation economic model.

Conclusions. 1. Factors affecting the prices of dry edible beans are as numerous and complex as for any major farm commodity, yet relevant data are limited in quantity and accuracy. It is difficult to identify effects of various factors on prices of a crop that can be stored, has several market outlets, is subject to government price support and distribution programs, and is traded in foreign markets.

2. Current production or total supply of each major class has been the most important single factor associated with variation in annual average prices. The negative relationship was particularly strong for Red Kidneys in New York and Limas and Blackeyes in California.

3. The effect of supplies of competing classes on prices of major classes was apparently minor in some cases and not significant in others. Total combined supply of Pintos, Small Reds, and Pinks appeared to have a significant effect on season average farm price of Red Kidneys in New York.

4. Time trends apparently have had an unfavorable effect on prices of Red Kidneys, Pintos, Large Limas, and Blackeyes. The price-depressing factor could be any combination of changes that have been developing over the 1948-62 period. This could include rising consumer incomes, changing living and eating habits, the growth of convenience foods, or all three.

5. The one class not showing a negative net relationship between price and time was Michigan Pea beans. Production and carryover have explained about three-quarters of the variation in annual prices of this class. Lack of a negative influence of time on price may be due to growth in the canned market for Pea beans. The decline in price that has occurred has apparently been due to increase in per capita production.

6. The price-making forces for California Blackeye beans are not complicated by government price support programs and foreign trade. It is possible to identify with greater certainty the important factors influencing production and prices of this class. Changes in production and prices of Blackeyes show more year-to-year variation than do classes subject to price support.

7. Changes in production of Blackeyes have been largely associated with changes in prices paid the previous year and carryover stocks. Prices in turn were closely related to total supply, including both current production and carryover. Carryover stocks in turn were largely dependent on the total supplies of the previous season. This set of relationships shows that low prices are likely to be followed by reduced production, bringing higher prices and consequently higher production.

8. Using this set of relationships as an economic model it was possible to simulate the changes over time that are likely to occur in Blackeye production, prices, and stocks. This provides an opportunity to study the amplitude and length of cyclical fluctuations in these economic factors. Wide variation in prices and production may be expected, with cycles ranging from 2 to 5 or more years in length.

MAINTENANCE OF DRY BEAN QUALITY DURING TRANSPORTATION, HANDLING, AND STORAGE

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In Market Quality Research Division, we have worked on three projects in the area of dry bean quality during the past few years. I have been associated only with the latter phases of these studies. Jud Thompson, now retired, initiated this work and carried it through most phases. His article, "Comparison of bag and bulk shipments of dry edible beans," came off the press only last week at ARS 51-3.

This work was initiated several years ago and was reported in part to this group at a previous meeting. Because canners and other processors objected to the condition in which bagged pea beans arrived, studies were made to determine whether more efficient transportation such as bulk shipments are available or could be developed. Ten tests were made over a 2-year period with bagged beans shipped by rail and by truck and rail in bulk and in bulk boxes. Under various combinations of stacking containers, type of transport, and methods of loading and unloading used, bean quality was maintained.

Specially insulated (RBNX) Fruit Growers Express cars were modified with sloping floors to the center door and lined with marine plywood so that bulk beans could be unloaded by gravity. This modified insulated car reduces temperature and moisture fluctuations during transit and helps to maintain the quality. Because of ease of loading and unloading, this car is also preferred to the standard noninsulated boxcar. Recently there have been improvements of insulated dual-hopper cars in providing unloading from the bottom and this feature provides even greater ease of unloading than the modified insulated car.

Each bag was probed at a designated spot marked before shipment to correspond to the position at which the original probing was made. In addition, the bag was probed at random. Sampling at marked spots gave more accurate analyses than did random sampling. In bulk shipments a pneumatic probe was used at destination to sample the beans; it was almost impossible to reach the bottom of the car with a standard grain probe because of settling. A similar probe (Probe-A-Vac) is now available from Cargill, Inc., Minneapolis.

Advantages of bulk shipping include elimination of the long and costly process of bagging and sewing, the need for bag conveyors and handtrucks, the tedious hand-stacking operations, cost of bulky pallets, and expense of dumping, cleaning, and marketing second-hand burlap bags. Loading time is reduced nearly 75%. Using the same crew (five men) it takes about 50 minutes with a flexible tube or conveyor belt to fill a hopper car with bulk beans, compared to 3-1/2 hours for the bagged product. As a final advantage, bulk shipping makes sampling much easier and more representative. The inspector gets a more representative sample from a pneumatic bulk probe or from the continuous flow of beans than he does by probing 10% of the bags.

The second research report was published as AMS-519 in 1962 entitled, "Maintaining quality of pea beans during shipment overseas," by Jud Thompson.

Mr. Thompson solved an international mystery when he accompanied a shipment aboard a freighter. Foreign buyers were complaining that beans arrived in a moldy condition and in torn bags. Yet, there was good evidence that these beans had left the US in sound condition. Mr. Thompson found that molding was due to excess moisture in the holds and torn bags were the result of rough handling during removal from the ships. The problem was solved by packing the beans in heavier bags (12 oz.) with more care in loading and unloading and also by controlling humidity aboard ship. He recommended installation of fans to improve ventilation and to control humidity in the holds which at times reached 100%. Aeration reduced the moisture content of surface beans even below their original moisture content, thereby reducing the hazard of spoilage.

Finally, I'd like to report on the use of burlap and multiwall paper bags for pea beans. A report was published earlier this year as AMS-528. In this study, work was done to compare the effectiveness of burlap bags and two types of multiwall paper bags for transportation, handling, and storage of 100 lbs. of dry edible beans at country points and terminals. The purpose was to compare quality of pea beans in multiwall paper shipping bags and burlap bags. No insect control was exercised. Cost comparisons were not studied. Burlap bags are generally being used to ship and store dry beans today. The study was designed to answer the following questions:

1. How do Type C (smooth) multiwall paper bags compare with Type D (ribbed) multiwall paper and burlap bags with regard to rough handling and stacking during shipment?
2. Can multiwall paper bags be sampled in the normal manner with a probe?
3. What is the relative merit of multiwall paper bags and burlap bags as barriers for moisture, color maintenance, and for other quality factors of beans?
4. Do multiwall paper and burlap bags maintain sanitary conditions?

Three types of multiwall paper shipping bags were made from four plies of extensible kraft paper. Closures were machine-sewed. Two separate storage studies were made. One lot of pea beans was stored for about 6 months in northern warehouses; the second lot was stored in southern warehouses for about 4 additional months. All pea beans used were graded U. S. Choice Handpicked according to the United States Standards for Beans.

In the first study, five carloads (1,000 multiwall paper and 3,000 100-lb. burlap bags) were stored for about 6 months at Bay City and Owendale, Michigan, before shipment. Fat acidity and moisture and color tests were made monthly. Samples were drawn from about 20% of the bags selected at random. Special effort was made to sample in the same area of each bag at successive samplings. For the second study, some of the bagged beans were stored in southern warehouses. A lot of 150 bags (50 of each of the 3-bag types) was shipped by rail in December to commercial warehouses at each location: Richmond, Virginia; Logan, West Virginia; and Houston, Texas. In addition, one lot of 150 bags was retained at Bay City, Michigan. The bags were checked while being loaded into the boxcar to determine how well the paper and burlap bags had held up during the 6 months of summer and fall storage in Michigan.

Preparation of the three railroad cars before loading helped prevent in-transit damage to the bagged beans. The walls of each car were examined for protruding nails and other projections by drawing a board along the walls. Walls and floors were covered with car liner paper. Retaining strips covered the doors. These strips kept the bags away from the doors and prevented damage that might have been caused by shifting of bags into the doorway. At each destination the bags were inspected for damage and then removed from the boxcar and stacked one upon another on three pallets. Each slatted pallet held 50 bags about 4 inches above the floor and about 2 feet from the wall and from other pallets. The bags were stacked flat on the pallets and even with the edges, with the end sacks interlocked. There was no apparent condensation of moisture on the surface of the bags or on the beans during the warming up period to warehouse temperature.

Representative samples of beans were drawn by probing every 2 months for analysis for moisture content, fat acidity and color, and checked for musty odors and mold growth. A special pressure-sensitive tape was used to seal the paper bags which had been torn during probing. In resealing paper bags during cold weather, the area to be taped was wiped free of dust and warmed by the sampler's hand. Moisture content was determined on 250 grams with a Motomco meter. Fat acidity values were determined on 100-gram samples according to the method of Baker and others. Color of 75-gram samples was checked with an Agtron reflectance meter. Mold growth was determined on individual beans sampled at random with a stereomicroscope.

There were no significant changes in fat acidity, moisture content and color of the beans in any lot during the initial 6-month storage at Bay City, Michigan. In addition, every bag was inspected before loading and found to be in good condition, probably because these beans had been stored on pallets with good air circulation. During the 4-month storage in the three southern warehouses, rate of moisture change in paper bags was about the same as in burlap. No significant differences in fat acidity were found; however, slight differences were noted in color readings for beans in all three types of bags because the beans darkened. No musty odor or mold growth was detected.

The moisture data indicate that stored bagged beans exposed to the atmospheric conditions normally found in Michigan contain about 14 to 15% moisture during the first six months (summer and fall) and about 11 to 13% when stored in southern commercial warehouses during the next four winter and spring months. This shows that four-ply multiwall paper bags as well as burlap bags permit the passage of moisture vapor through the walls.

Evidence of deterioration in dry beans can normally be detected when the fat acidity value exceeds 40. Values obtained in this study showed no significant increase in fat acidity value from beginning to after 10 months of storage. None of these values exceeded 20 in either paper or burlap containers, which indicated no deterioration.

Observations of the authors and comments of employees of the school lunch program who used the beans showed that beans stored in paper are free from the dust, dirt, lint, and thread often found in beans in burlap bags. School lunch program officials at Richmond, Virginia; Logan, West Virginia; and Houston, Texas, recommend 50-lb. bags because the 100-lb. bag is awkward to handle.

No significant changes in color, fat acidity, and moisture content were found in beans stored in paper and burlap bags during the initial 6-month period at Bay City, Michigan, and during the additional 4 months in the four commercial warehouses. Multiwall paper bags seemed to bridge areas better than burlap and hence to stack more evenly. However, Type C multiwall paper bags were smooth (not ribbed) and were more difficult to handle and stack than the ribbed Type D multiwall paper bag. The use of the special pressure-sensitive tape was quite effective in resealing punctures caused in probing the multiwall paper bags, especially if the area taped was dry and free of dust. In no instance, during the storage periods, was there any evidence of failure of the tape to adhere to the paper bags.

CONTROL OF HALO BLIGHT WITH STREPTOMYCIN

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New York Agricultural Experiment Station, Geneva

Halo blight has been a problem of increasing concern to New York snap bean growers for the last 3 years. Observations in field plantings and the greenhouse indicated that the blight originated from infected seeds produced in Idaho. As a result, some New York growers are seriously considering production of their own seed. At the Geneva Station, however, we have told our growers that until control of seed-borne diseases can be obtained, the practice of growing bean seeds in New York should not be recommended.

In 1963, studies were conducted to determine the value of streptomycin in eradicating halo blight from plants originating from infected seeds and also in protecting healthy plants from the spread of the disease. Alternate 2-row plots of disease-free Red Kidney bean seeds and seeds of Kinghorn Wax beans harvested the previous season from a field which was severely infected with halo blight were planted in an isolated location. To a portion of this planting, 7 streptomycin sprays were applied at about weekly intervals starting when the primary leaves unfurled. To another portion, 12 streptomycin sprays were applied in a similar manner. Unsprayed plots served as controls. The streptomycin was applied at a concentration of 200 ppm and at a volume of 28 gallons per acre. Sprays were applied in the evening to permit maximum absorption of streptomycin by the plant. Data on incidence of seed-borne halo blight were taken before any secondary spread occurred. The progress of halo blight was determined by periodic counts of the number of infected plants.

Only about 0.5% of the Kinghorn Wax seed was found to be infected even though the planting from which the seeds were obtained was completely infected. No seed-borne infections were observed in the Red Kidney beans. Streptomycin did not eradicate systemic infections in plants originating from infected seeds. However, it provided some control of the spread of the disease. At harvest, 86% of the Red Kidney bean plants which had not been sprayed were infected. In plots receiving 7 streptomycin sprays, 73% of the plants were infected. In plots receiving 12 streptomycin sprays, 46% of the plants were infected. Most of the spread of halo blight in the 7-spray plots occurred after the sprays were discontinued.

Seeds harvested from the sprayed plots and the untreated plots in 1963 were planted in 1964. Data were taken on the incidence of infected seeds in the various seed lots. In the seeds harvested from the untreated plots, 1,420 plants with seed-borne infection were counted among a total of 23,400 plants. In the 7-spray streptomycin seed lot, 156 infected plants were counted among 28,512 plants. In the 12-spray streptomycin seed lot, 75 infected plants were found among 77,220 plants. No infected plants were found among 10,200 plants of certified Red Kidney bean used as a control to check for air-borne and soil-borne inoculum. These data show that streptomycin is of considerable value in preventing seed-borne infections. Further studies on halo blight control with streptomycin are planned for next year.

INHERITANCE OF TOLERANCE TO COMMON BLIGHT AND BACTERIAL WILT IN *PHASEOLUS VULGARIS* L. FIELD BEAN CROSSES

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University of Nebraska, Lincoln

The inheritance of common blight, caused by *Xanthomonas phaseoli* (E. F. Sm.) Dows., was studied in two *Phaseolus vulgaris* crosses involving the early-maturing susceptible Great Northern (GN) variety 1140 and 2 late-maturing tolerant GN Nebraska No. 1 selections. The parental, F_2, and backcross generations were grown in the field in 1963 and 1964 and inoculated with a bacterial suspension. The continuous nature of the variation in the disease ratings in the segregating generations suggested that the disease reaction was inherited quantitatively. High heritability estimates were obtained in different years using the components of variance method. A low estimate of heritability was obtained using the regression of F_3 progeny means (1964) on individual F_2 plants (1963). The low estimate was due to different degree of infection obtained in these plots. A significant negative phenotypic correlation of -0.34 was obtained between disease tolerance and time of flowering. The low value indicates that earliness of maturity and disease tolerance can be combined. F_3 progeny derived from early-maturing disease-tolerant individual F_2 plants were grown in 1964. The actual gain in tolerance to disease appeared to agree fairly closely with the predicted gain based on the heritability estimate calculated in 1963.

The inheritance of tolerance to bacterial wilt caused by the bacterium, *Corynebacterium flaccumfaciens* var. *aurantiacum* Schuster and Christiansen, was studied in *Phaseolus vulgaris* crosses involving 3 susceptible parents (S) x tolerant (T) parent as follows: Great Northern (GN) Nebraska No. 1 (S) x PI 165078 (T); GN Nebraska No. 1 selection 27 (S) x PI 165078 (T): GN 1140 (S) x PI 165078 (T). The F_2 of the first cross was grown in 1963, F_2 of the second cross and F_3 families derived from tolerant F_2 plants of the first cross were grown in 1964. The data suggest that the susceptible reaction is determined primarily by two complementary dominant genes, the absence of any one or both genes resulting in tolerance. In view of the mode of inheritance of bacterial wilt tolerance in the first 2 crosses and the quantitative genetic nature of common blight tolerance, a backcross program was proposed to combine tolerance simultaneously to both of these bacterial diseases.

In 1964 the parental, F_1, F_2, and backcross generations of the cross GN 1140 x PI 165078 were grown in the field and inoculated with the wilt bacterium. The data suggest that the disease reaction in this cross was inherited quantitatively. A high heritability estimate, calculated in the "narrow sense," was obtained.

NATURE OF TOLERANCE TO BACTERIAL WILT IN PHASEOLUS SPECIES

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University of Nebraska, Lincoln

Young plants of susceptible (*Phaseolus vulgaris*) var. Great Northern (GN) and tolerant (*Phaseolus vulgaris* var. PI 165078 and *Phaseolus acutifolius* var. *latifolius*) beans were inoculated by removing one cotyledon and then inserting into the wound a dissecting needle dipped into a water suspension of *Corynebacterium flaccumfaciens* var. *aurantiacum*. The bacterial populations in the stem internodes were determined by plating weekly for a period of 7 weeks. The bacteria multiplied in all 3 kinds of beans. The increase in bacterial populations was very rapid in GN 1140. The number of viable bacteria increased gradually in PI 165078, but never reached large proportions even in 7 weeks. Tepary contained a fairly high number in 4 weeks, but subsequently the populations decreased rapidly.

A negative correlation was found between bacterial population and height of the inoculated plants. The bacterial populations in Tepary and GN 1140 reached their peak 4 weeks after inoculation. The growth curves for both varieties were almost horizontal for 3 weeks. Upon decrease of bacterial populations, the Tepary variety tended to grow normally. The inoculated plants of PI 165078 grew normally in a gradual curve.

The bacteria reached the uppermost nodes of the susceptible much sooner than of the 2 tolerant bean types. One month after inoculation bacteria could not be found in the upper 25% of the nodes of the tolerant beans although they were prevalent in the susceptible variety.

Seed infection was evident in GN 1140, but a lower percentage was present in PI 165078. No visibly infected seed of Tepary was observed.

DIRECT COMBINE HARVESTING OF DRY BEANS

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Initial tests conducted in 1958 at Cornell University indicated that direct combining of dry beans was possible. However, to be commercially feasible, the total loss would have to be less than 1-1/2 to 2 bushels per acre. Consequently, during 1959, 1960, and 1961 main emphasis was placed on developing a direct harvesting combine. Additional efforts were made to improve the existing methods of bean harvesting.

Several different harvester components were field tested. If these units would work satisfactorily, they were to be incorporated into the design of a direct combine harvester. In 1961, I reported on various devices and experimental units that were designed, constructed and field tested. These included: (1) a two-row hydraulically powered rotary cutter (Hopkins Mfg. Co., Saginaw, Michigan), (2) an experimental single belt puller, (3) a completely self-propelled combine with four different attachments for direct combining: (3.1) rubber fingered belts driven by traction wheels to lift beans over cutter bar, (3.2) improved rubber-fingered belt device with rotating spiral brushes to help lift the beans before cutting, (3.3) a 3-inch-wide double belt puller attachment with sponge rubber surfaces, and (3.4) a complete rubber belt pulling device, with which best results were obtained. This unit used two belts (Goodyear, Rough Top, Diamond Cut) 18 inches high. The two halves of the pulling device were spring-loaded to permit spreading when striking an obstruction. The belts were powered by hydraulic motors. The wide-belt pulling attachment worked very satisfactorily under all field conditions.

Where the bean plants were lodged, the belts lifted the beans to an upright position before they were pulled. With a belt speed of 250 to 300 fpm, and forward speeds of 1 to 2 mph, losses were slightly less than 1 bushel per acre. Results with the single row belt puller device were so satisfactory that for the 1962 season, a four-row harvester was designed and constructed. The four-row harvester consists of a reconditioned Pioneer bean harvester (Pioneer Thresher Co., Shortsville, New York) mounted on a unitractor power frame (Minneapolis-Moline Farm Equipment Division, Motec Industries, Hopkins, Minnesota). The standard pickup and elevator were removed from the harvester and a 12-foot Massey-Ferguson grain combine header and elevator (Massey-Ferguson, Ltd., Toronto, Canada) was mounted on the self-propelled harvester unit. Four identical puller units (Bliss Machine Co., Savannah, New York) were then attached to this 12-foot header.

The puller belt attachments were identical with the single row previously described except for the mounting arrangement. The two halves of the puller are vertically supported on a square tubular frame and are spring-loaded to permit spreading when striking an obstruction. The frames, in turn, are attached to a five-inch steel tube in such a manner that they are free to pivot on a horizontal axis. The attaching clamps are movable to permit lateral adjustments for various row spacings. In addition, two small pneumatic-tired wheels were mounted on each unit to support part of the weight of the attachment to allow the individual units to follow the terrain.

Power for driving the pulling belts is supplied by four hydraulic motors, one for each set of belts. A roller chain and idler drive permit the two rear driving rollers to separate if required. The hydraulic motors are driven by a hydraulic pump which is, in turn, powered by an auxiliary gasoline engine mounted on the rear of the harvester. A flow divider valve is used in the hydraulic system as a convenient method for changing the pulling belt speed.

During the 1962 harvest season, main emphasis was placed on establishing the feasibility of a four-row direct harvester as an improved harvesting tool for dry beans. The harvest was severely hampered by unusually heavy amounts of rain which stopped harvesting almost completely for more than two weeks.

However, the four-row machine was field tested in three different areas of the State, Savannah, Lansingville, and Seneca Castle, which constituted a good variety of plant and soil conditions. The field tests were conducted in a manner similar to those of the 1961 season. Bean loss counts were taken at different ground speeds and belt speeds to determine the optimum belt-ground speed ratio for minimum bean loss. A further objective of the tests was to iron out the mechanical "bugs" inherent in an experimental machine, to the point of being able to proceed continuously along the bean rows with little or no need for adjustments. This latter requirement necessitated a number of refinements and modifications as the season progressed.

Results of the 1962 season using the four-row machine were about comparable with the single-row unit. Minimum losses of approximately one bushel per acre were obtained with a belt-ground speed ratio of approximately 2.5 to 3. Some problems were encountered with excessively hilled beans because of alignment difficulties. Other problems with the Pioneer combine were experienced early in the season but added repairs corrected this fault. After the 1962 season, the Agricultural Engineering Project on direct harvesting was terminated. It was felt by almost everyone concerned that a commercially feasible four-row machine had proved to be successful and that it was now up to industry to make it available to interested growers. Consequently, a determined effort was made to interest large and small farm manufacturing companies to take over the Cornell harvester. While several companies expressed an interest, and one large company indicated that they would build a prototype machine for the 1964 harvest season, no results are evident.

In the summer of 1963, one of our senior students in Agricultural Engineering, Don Betzler, expressed an interest in the four-row harvester. With his father he grows a considerable acreage of dry beans and also runs a farm implement company. Arrangements were made to loan Mr. Betzler the four-row attachment in exchange for additional information on direct harvesting. During the summer and fall of 1963, the four-row unit was modified slightly to overcome some oil heating problems and was mounted on a rebuilt John Deere self-propelled combine. The entire modification and mounting of the unit was not completed until late October 1963. After some additional delays, due to rainy weather, approximately 10 acres of beans were harvested with the machine. Although loss counts were not taken, they appeared to be about the same as in 1962. The same self-propelled direct harvester was again used by Mr. Betzler during the 1964 season. Results were the same as 1963.

BULK BREEDING IN LIMA BEANS

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Lima beans have been grown as a commercial crop in California for over 100 years and as with many other crops that have been well adapted for a given area, probable progress toward higher-yielding good-quality types is slow and to say the least tedious. Since only small gains in yield can be expected it is therefore important that we do not overlook all sources of combinations from hybridization, because it is through hybrids and their subsequent segregants that yielders will be uncovered.

The most common method of exploiting variability following hybridization is through pedigrees. An alternate approach would be to use bulk populations. Mr. Suneson of the USDA, stationed at Davis, California, calls this an evolutionary plant breeding method, because it relies on natural forces for selection toward higher-yielding adapted varieties. Briefly, all that is involved is that several hundred or thousand F_2 seeds are planted under commercial rates. Each generation is planted from a sample of seed taken from the preceding generation. Normal commercial cultural practices are generally used. Artificial selection can be imposed at any point in the progress of the breeding program. Testing of the bulk and selected lines can be done in a number of ways.

The pedigree method has some deficiencies when applied to lima beans: (1) variability among lines or families is subtly expressed at the Field Station at Santa Ana so that visual selection has little or no meaning; (2) the number of seeds per plant is quite low because of large size, which limits testing; (3) it seems evident that a number of hybrids should be utilized if we hope to develop higher-yielding varieties. Only a limited number of pedigrees can be used because of the space and time each takes.

Another problem plant breeders are faced with relates to genotype-environment interaction. If a crop is grown in a number of distinct environments and it is evident that there are differences of adaptation among genotypes, then the breeder must decide whether he should select in only one environment, at an experiment station perhaps, or should select lines at random followed by an intensive testing program in each growing area, or should select in each environment. We know that it is generally more efficient to confine breeding nurseries to experiment stations. An alternative is to grow bulk populations in each environment.

We know that natural as well as artificial selection causes changes in gene frequency from generation to generation. Forces of natural selection or differences of viability and fertility are always present; however, they may not always be complet ly relevant to a practical breeding program. The issue then is whether natural selection leads to higher yielding varieties, and does it do it in an efficient way.

Published data on bulk populations seem contradictory. Studies of Laude and Swanson, Suneson and Stevens indicate that competitive ability is not necessarily related to yielding ability in barley and wheat populations. Suneson has results from 4 hybrid barley populations which show progress toward higher yielding ability as generations increase. A number of released varieties (mostly barley) have originated from bulk populations.

The results from two lima bean bulk populations grown in California have been summarized. The first, designated Bulk 51, was started by Dr. Allard at Davis from 2 crosses which were combined in F_3. The only artificial selection was for seed coat color in the F_3 and seeds were sized with a 32 screen. These populations were grown at Davis until F_9. They were then transferred to Santa Ana. In the F_{11}, 200 single plants were selected at random. Of these, 175 were saved and grown in progeny rows. A total of 11 lines homozygous for seed coat color and growth habit were used for testing.

The other population, designated I453, was started from some natural hybrids originating in a yield trial located in a grower's field near Santa Ana. The grower grew the population in isolation until F_5. In F_6 he had enough seeds for a 15-acre planting. By the F_9 this seed stock was grown on 800 acres. No artificial selection was done on these populations. In F_7, 300 single plants were selected at random from commercial fields. A random sample of rows homozygous for growth habit and seed coat color were chosen for testing.

The results of tests comparing Bulk 51 and L41 (the variety Ventura) show Bulk 51 with a significantly higher yield which indicates that there is selective advance through natural selection. Yields of Bulk 51, a composite of 11 lines from Bulk 51 and L41, were compared. Although the data are not significantly different, the results suggest that the composite of 11 lines are as good as Bulk 51 and L41. Visual quality of the composite is better than Bulk 51 and L41. Mean yields of the 11 selected lines from Bulk 51, a composite of the 11 lines and L41, were not significantly different; however, the differences would indicate that further advance through artificial selection may be possible. There is also a suggestion of no facilitation because the mean of the 11 lines is approximately the same as the composite of the 11 lines. Mean yields of 13 lines from I453 and L41 were given the multiple range test. A total of 6 significantly different groups with L41 in the middle group can be recognized. Advance through natural selection is evident here and further advance through artificial selection should be possible.

In summary: bulk population breeding does have a significant place in lima bean breeding in California. Progress toward high-yielding types resulting from natural forces can be expected. Further progress may be made by artificially selecting among pure lines in late generations.

VARIATIONS OF PHOTOSYNTHETIC EFFICIENCY AMONG BEAN VARIETIES

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Applying methods of growth analysis, D. H. Wallace concluded that differences in net assimilation rate (NAR) may exist among some dry bean varieties. In the present study another method to detect NAR was applied, that is, measuring the net CO_2 exchange of the leaf. This is based on two assumptions: that leaves carry out most of the photosynthesis and that about 95% of the dry matter is composed of carbon compounds derived from photosynthesis.

The technique of the leaf chamber is described by Musgrave (Crop Science 2:311-315, 1962). Several varieties were included in preliminary experiments. Plants of the same age were tested at the primary leaf stage and on first trifoliate leaves. Leaves connected to the whole plant were placed in the chamber for about 30 minutes, of which the first 15-20 minutes were taken to approach an equilibrium, that is, to a constant amount of CO_2 uptake.

The experiment included 3 levels of light intensity, 1100 fc, 3300 fc, and 7500 fc. The plants were grown in the greenhouse under fluorescent light. Michelite-62 (pea bean type) showed higher CO_2 uptake than the other varieties. For further studies Michelite-62 and Perry Marrow were chosen. The data show that with primary leaves the advantage of Michelite-62 at 3300 fc is 40% as compared with Perry Marrow. The advantage is about 17% at 7500 fc. However, the higher the light intensity the higher the NAR values. Trifoliate leaves showed 16% advantage for Michelite-62 at 3300 fc but the same NAR at 1100 fc. Statistical analysis indicates the differences between the two varieties to be highly significant. It is not known yet whether these differences in net exchange are due to high CO_2 fixation or low respiration rate. Further physiological and genetical studies on factors controlling these differences are still under way.

INDUCTION OF VARIATION IN A BEAN POPULATION BY A COMBINATION OF RECURRENT INTERCROSSING AND NEUTRON IRRADIATION: CYCLES ONE AND TWO

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This study was designed to see whether a plant breeder could work within an already highly selected or elite population and create useful variability for selection purposes. The underlying principles are that in an elite set of lines linkage disequilibrium is likely to be extensive and that new linear gene sequences could be promoted by recurrent intercrossing (up to four generations) coupled with irradiation to produce chromosomal breakage or enhanced intrachromosomal recombination. This report is preliminary in that only the first two (of four projected) cycles have been carried to completion. Cycles three and four will be field-grown in 1965, after which a more complete answer should be possible.

If repulsion phase linkages predominate for genes conditioning a given trait, then enhanced variances in the test generation would be expected. If coupling phase linkages predominate, the test variances would be expected to decline. We have data on mean squares among randomly selected progeny rows within lines in the F_4 generation following none (P), one ($1C_1$), or two ($1C_2$) generations of intercrossing, where the parental generation consisted of 150 progenies tracing to 10 original homozygous parental lines, the $1C_1$ consisted of 450 progenies tracing to 45 single crosses involving the 10 parents, and $1C_2$ consisted of 1780 progenies tracing to 178 lines produced by intercrossing the 45 single crosses. For comparison a paralled set of nonirradiated lines (control) and neutron-irradiated lines was grown.

For pods per plant, intercrossing appears to have reduced the variability slightly, whereas radiation has a small enhancing effect, suggesting that intercrossing is tending to break coupling linkages, and that radiation is slightly mutagenic tending to contribute to increase in variance. This is supported by the increase in variance of the parental progenies that had received irradiation.

For seeds per pod, both radiation and intercrossing enhance variance. With respect to weight per 100 seeds, intercrossing increases variance as expected in the nonirradiated population and in the irradiated population as well but the effects are apparently confounded, with lowered variance in the P-set due to radiation.

Finally, with respect to seed yield, there appears to be a progressive increase of variance with recurrent intercrossing and with radiation. It must be emphasized again that these results are based on only the first two generations of a planned four-generation experiment, and therefore the results, though encouraging, are still inconclusive with respect to attainment of the principal objective.

INTERPLANT COMPETITION IN BEANS AND CHANGES IN COMPOSITION OF VARIETAL MIXTURES OVER A 5-YEAR PERIOD

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We report here on two related studies conducted concurrently in Michigan in the period 1959-64 inclusive. They were based upon two related ideas: (1) Plants of differing developmental patterns must make slightly differing demands on the environment for resources, so that greater total exploitation of an environment should be possible with a heterogeneous population than with a homogeneous population. (2) Natural selection operating in a heterogeneous bulk population sifts and winnows all genotypes and growth patterns, preferentially increasing those of greater competitive ability, to give populations at higher and higher levels of fitness, until some equilibrium is reached.

The plant breeder is interested in the dynamics of heterogeneous populations of inbreeders for two reasons: (1) Creation of a superior-performing "variety" by bulking of two to many lines. (2) Creation of superior populations in which to select pure lines of greater competitive ability by growing composited mixtures or hybrid bulks over a great many generations.

The breeder has many questions to which he would like reasonable answers, for example: (1) In what respect are bulk mixtures superior? (2) What traits change over years, and at what rates? (3) What kinds of phenotypes give best bulks? (4) Is competition greater between genotypes that are so similar as to make similar demands upon the environment at similar times? (5) Can composites be put together in such a way as to be superior over pure lines and to remain stable in composition for up to 5 years?

In the first experiment we compared competition between plant types: early versus late maturity, and vine-type versus bush plant form. Experimentally we had 4 genotypes, giving six 2-line mixtures and 4 pure-line plots, grown in 5 replications at each of 2 locations in 1962 (2", 4", 8", 16", and 32" spacing within plots). We devised a competition index as shown:

$I_c = \frac{(D_m - D_p)}{S_{dp}}$, using the t-distribution for testing the significance of differences.

D_m = difference between lines A and B when in competition in a 2-line mixture.

D_p = difference between lines A and B when in pure stand.

S_{dp} = pooled standard deviation of differences.

Results: (1) The indeterminate vine is favored in competition with the bush-plant type, at all levels of maturity. (2). The late-maturing type is favored over the early-maturing type, at both levels of plant form. (3) The late bush competes about equally with the early vine.

Predictions: (1) Early vine would persist longer than early bush in complex varietal mixtures (other things being equal). (2) Late vines tend to dominate over everything else. (3) Late bush would tend to dominate over an early bush.

The 5-year experiment involved 10 mixtures each composed initially of 2 lines in a 1:1 ratio. Seed harvested in 1959 (year 1) was planted in 1960, etc., except that a portion was saved for final testing after the 5th year of being grown <u>en masse</u>. Thus in 1964 we had 10 mixtures for each of 5 years. These were planted in 5 replications with plots consisting of 4 rows each 20 feet long. Plant counts were made at flowering and at or during ripening to determine the proportion of each component present. Results for No. 8211 (early bush type): (1) A steady decline in frequency as the competing line becomes later or becomes a vine type in each year. (2) Approximate fitness index reflects the competitive ability of No. 8211 in various combinations. (3) Simple mixtures undergo sudden and drastic changes in composition with slight evidence of any oscillatory patterns.

<u>General conclusion</u>. With each increment of delay in maturity, and/or change to vine plant type, the competitive effect increases--the survival of the least competitive line becomes less probable, or its eventual loss becomes more certain. <u>Earlier predictions are confirmed</u>. <u>Significance</u>: Mixtures (or composite varieties) that are expected to retain their initial composition as an equilibrium value must not be made up of lines that differ in maturity or in plant type. No evidence of fitness any higher than the more competitive component. The question is left open as to the compositional stability of composites even when these are made up of approximately similar phenotypes.

FAS FUNDS FOR PROMOTION OF FOREIGN TRADE IN BEANS

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I was asked to discuss "methods and requirements for obtaining funds from FAS for foreign market development." After pondering this title, it occurred to me that uppermost in the minds of those who might be contemplating foreign market development would be two brief questions--(1) how does a group qualify for PL 480 market development funds, and (2) how much money can a group get?

It would have been convenient if the Congress had spelled out the answers in the PL 480 statutes. Congress left it to the Department of Agriculture to develop this program by way of administrative decision. A major decision made in the beginning some 10 years ago was that, to the extent possible, these programs should be carried out under cooperative arrangements between commodity groups in industry and government. Industry was to be primarily responsible for initiative and leadership and FAS to provide foreign funds and service. Since that decision, many have been made on each commodity program. Some affect only that commodity. Therefore, to answer our questions we are obliged to review decisions, especially those pertaining to the bean program.

Bean promotion. The first foreign market development work undertaken on beans was in 1957 with Western Bean Dealers, Inc., of Twin Falls, Idaho, as the first cooperator. They were first because, in 1957, they were the only organized pulse group to express interest. They had personnel available and were interested. The first step was the signing of two formal agreements with FAS. The first is known as the program agreement. It is a broad, long-term contract having no termination date and committing no funds. It is essentially a memorandum of understanding, spelling out certain policy issues which, by law, must be adhered to. There are several policy matters covered but only one need concern us. It is that the cooperator will stimulate the interest of other US groups to participate including producers, processors, and other trade groups.

FAS prefers to deal at the program agreement level with as few organizations on any one commodity as possible. It is hoped that all bean promotion at least, and if possible pea and lentil promotion, might be coordinated and funded through one organization. Cooperation should be nation-wide or industry-wide so far as is practical. FAS is not staffed to support several groups in one commodity field; we must avoid overlapping or duplication. For these reasons, FAS supported the transfer of the program agreements from the Idaho Association to the National Council. It seemed logical and right to bring all bean groups under the Council rather than under one of its five member associations. Another reason (though not the major one) was the Council's Washington Office. Every cooperating group has found it advisable to have representation in Washington. FAS experience has demonstrated that Washington representation is almost a "must" in effective work.

It was the clear purpose and intention when agreements were signed with the Council that all interested parties in the US pulse industries might eventually participate under the Council's umbrella if they chose and could qualify. Any industry group engaged in the production, processing, or trading of agricultural commodities can qualify for the PL 480 funds provided it can and will work with other groups engaged in the related industry and can meet the legal and administrative requirements of FAS. The method of getting into the program, therefore, is through application to the National Bean Council who has the program agreement with FAS, and whose obligation is to encourage participation of all other groups interested in pulse market promotion under PL 480.

Financing bean promotion. The second, or project agreement, first signed with Idaho and now with the Council, contains four major parts: (1) a statement of the objective of the work to be done, (2) language justifying the work to be done, (3) explanations on how the work may be done, and (4) a commitment of the funds to be provided by FAS and the cooperator and a tabulation of the intended use of these funds.

In the beginning, 1956-57, FAS was lenient, asking cooperators to provide only a small ratio of the total resources. Cooperators soon found, however, that to do even a modest job they had to put forth much more in the way of resources than those early contracts called for. As the program grew, a general rule of 2 to 1 financing was developed. Under this rule, FAS provides 2 for 1 or an industry requirement of 50 cents to the FAS dollar. In several of our hard-sell promotion programs cooperators contribute dollar for dollar and in some cases it has been 5 to 1 with industry providing the 5. None of these ratios, however, has much practical application to a new program, as the following review reveals.

Since 1957 some $45,000 of FAS funds have been spent in bean and pea programs. The Michigan Bean Shippers Association has contributed $10,000 in cash and the Michigan Bean Growers Association, $1,000. The US bean and pea industry provided the services of 29 men for 1 to 2 months each for travel abroad. They have spent several thousand dollars for living expenses of these men while traveling and have provided considerable backstop services preparing for these trips and for later reporting. It might be difficult to assess accurately the value of this service. But, in my opinion, this would cost considerably more than the $45,000 spent by FAS. Its value, however, is almost zero unless it can be made part of a continuing program.

The major problem encountered by newcomers in bean promotion likely will be finding and hiring qualified personnel and financing and supporting them. FAS has no funds for US salaries or for office space, equipment or supplies in the United States. New cooperators should expect that much of the first year will be spent in planning, organizing and initiating the work. Under these conditions, it is very probable that the industry contribution will far exceed that of FAS. It will continue so until actual work gets under way abroad on a substantial scale. Only then will the FAS contribution likely approach the 2 to 1 ratio expected.

New cooperators in bean promotion will find the limiting factor to be their own financial and human resources. FAS will do its best to find funds to team up with industry if industry can come up with a well thought out practical program. The cooperator contribution may be in the form of cash and services. FAS requires as a bare minimum that cooperators provide a staff competent to administer and supervise. Technicians loaned by industry can make excellent contributions--if they are skillfully fitted into a well-designed program. But, a program that is largely dependent on borrowed part-time help cannot be effective. A full-time paid employee is needed.

Once an overseas program gets under way cooperators should try to secure the cooperation of foreign industry groups. Since these groups stand to profit directly if sales volume increases, they can--and do--make significant financial contributions to joint promotion projects.

New cooperators and old should know and appreciate the fact that the bulk of the FAS funds they use today comes from the so-called soft currency countries such as India, Israel, Yugoslavia, etc. Of the 5% generated in these countries 2% can be converted to other harder currencies for market development purposes. The Swiss francs which fund the current bean project and are available to the Council through the US Embassy in Bern were probably Indian rupees or Egyptian pounds before conversion.

Accomplishments of bean promotion. Market development normally begins with market surveys. In 1957 two of your men visited bean markets in Latin America. In 1961 five of your men investigated the larger bean, pea, and lentil markets of England and Western Europe. Later in 1961 two of your men participated in the Food Exhibit in Hamburg, Germany, in cooperation with the German pulse industry. In 1962 a second team of three men from your industry revisited the principal bean markets of Latin America. Also in 1962 you brought a five-man team of European pulse importers to the United States to see your producing areas, processing facilities and to become better acquainted with US traders.

In 1963 a four-man team of US pea and lentil growers, dealers, and exporters surveyed the markets and competition in peas and lentils in South America. Also in 1963 a three-man team participated in a US pulse show at the Trade Center in London. In that same year, a five-man team made up of pea and bean dealers and one bean grower participated in the US Food Exhibit in Amsterdam and contacted pulse importers and canners in the European Common Market and in England and Switzerland.

In 1964 a three-man team participated in the Paris Fair and again labored with importers and bean canners. Surveying markets is not intended in itself to accomplish much market development. Nevertheless as a direct result of these surveys, the US bean industry is more aware of export markets and is doing a better job in selling and servicing. Conversely, foreign buyers know you and your industry much better. And, judging by the fewer complaints coming to FAS today, the quality of our exports has improved. Since these surveys began US commercial exports of beans have reached new high records. For the marketing year ended last September 30, US commercial exports of beans totaled 173,000 metric tons, the largest in history and more than a third larger than when the survey work began.

It is true that factors other than good will and quality have helped in this new record, for example, the cessation of exports from East European competitors and the drought in West Europe. On the other hand, it could be argued that these developments were more than offset by the loss of two-thirds of our one-time normal export market. Whereas Cuba and Mexico took up to two-thirds of our total exports a decade ago, today Cuba is "out" and Mexico is exporting beans. Still the United States is breaking all past records in bean exports.

But more direct evidence comes in a recent report from Holland. According to this report sales of canned beans in the Netherlands doubled in November-December and January 1963-64 over the comparable 3 months a year previous. The increase was attributed to the advertising accomplished at the Amsterdam Fair in November 1963. Those present recall that Amsterdam grocery shelves were barren of canned beans before the Fair itself was over. Further evidence is found in the London Financial Times of August 11, 1964:

"While frozen foods have been showing steady growth in popularity (in England) in recent years--something like 5% a year and probably more this year--and now form a $210 million market, their canned rivals might be thought to be trailing badly. But this is not the case. Canned vegetables have been just as active, and by 1962 retail sales totaled $210 million. The most buoyant section of the canned vegetable market has been Briton's staple diet of baked beans. Sales of these are now worth over $70 million. In the past three years production has jumped by about 30%. This dramatic growth reflects the advertising efforts of the major companies in this field--Heinz, Crosse and Blackwell, and HP Sauce--all of whom spent at least $280,000 each year in sales promotion, with Heinz spending even more."

Quoting the Financial Times is not intended to imply that bean market development programs should duplicate the high cost promotion of British canners. Rather a suggestion should be taken from the British and encouragement given to prospective canners outside England to follow the example set by Heinz, Crosse and Blackwell and HP Sauce. The present program in Europe is doing exactly that.

In conclusion, there is reason to believe that the future of dry beans or any other slow-cooking dry pulse lies in the processing field, canning or otherwise; and that nothing short of top quality will survive the future demands of processors. Quality and convenience seem to be the objectives of all workers represented at this research convention. To build markets "quality and convenience" must be the constant objectives.

STUDIES ON THE PRODUCTION OF PRECOOKED DEHYDRATED BEANS

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A process has been developed for the production of quick-cooking dehydrated beans. It involves hydrating the dry beans by soaking in water, precooking in steam, coating, and dehydrating. The process is satisfactory for a wide variety of beans including pea, marrow, black turtle soup, and red kidney. The processed beans are ready for consumption after covering with hot water and then boiling for 30 minutes. Several features are inherent in the process: (1) Butterflying the beans during cooking and dehydration which ordinarily results in loss of structure and identity is economically controlled. (2) Baked bean flavor and color are produced without a baking step. (3) The amount of brown color can be controlled by varying the concentration of dextrose in the coating mixture. (4) Storage beans with poor inherent cookability can be processed, yielding a quick-cooking product with a uniform and characteristically smooth texture when rehydrated. Details will be published in Food Technology 18(12): December, 1964.

EFFECT OF PROCESSING ON THE NUTRITIONAL QUALITY OF PEA BEANS

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In recent years research on plant proteins in the USA has been stimulated as a means of improving the amount of high-quality protein for human consumption. Changes in protein quality, due to processing, are probably insignificant so far as present nutritional well-being in the US is concerned. However, with our rapidly expanding population protein quality may become a problem later.

Investigations were undertaken to determine the effects of processing procedures on nutritive values of the protein of beans. The effects of underprocessing, overprocessing, and addition of carbohydrate during processing were investigated.

The feeding of raw pea beans as the sole source of protein to weanling rats results in death within 2 to 4 weeks. Pancreas data were evaluated as a means of assessing under-heat-processed pea beans. Generally, as the pancreas weight decreased per unit of body weight, the nutritive value of protein from pea beans increased, as measured by protein efficiency ratio. Soaking pea beans overnight was found to increase the nutritive value of raw pea beans. Soaking apparently removes some of the antinutritional factors present in raw beans, since all rats fed beans soaked overnight survived the 4-week period.

The utilization of pea beans cooked at 121°C. (250°F.) was studied. Generally, growth declined as cooking time was increased. Data indicated that protein efficiency ratio decreased drastically if pea beans were cooked 40 minutes or longer at 121°C. (15 psi). The addition of carbohydrate to pea beans after cooking caused a further decline in the nutritional quality of protein. Dextrose caused a greater decline than did a similar quantity of sucrose.

The data show that as new and more sophisticated foods are developed, there must be cooperation between food technologists and nutritionists in evaluating the nutritional quality of these new convenience foods prior to marketing.

CHANGES IN COOKING QUALITIES OF RAW BEANS AS INFLUENCED BY MOISTURE CONTENT AND STORAGE TIME

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Several years ago we studied the influence of moisture content on the keeping quality of dry beans. In that experiment involving six varieties, high-moisture samples developed unpalatable flavors in less than a year whereas lower-moisture samples remained excellent in flavor for two years. In the same experiment the higher-moisture samples stored one and two years were graded down in texture after a standarized cooking procedure. The subjective method used in this work did not permit a quantitative evaluation of the change in cookability.

A few years ago an experimental bean cooker was built in our shops. This cooker makes it possible for us to measure the cooking qualities of beans objectively and to assign a quantitative value to each sample. Since this cooker has been available, we have been studying changes in the processing quality of beans as a function of their moisture content. In these studies we have been using sanilacs from Michigan, pintos from Idaho, and large limas from California. The first report of this work, covering samples stored nine months, was presented at the Sixth Bean Conference in Los Angeles and is included in the published proceedings. Now, results on most of these samples after three years' storage will be presented. In addition some results of a second experiment covering a wider range of moisture contents stored at lower temperatures will be presented.

Experimental bean cooker. Before presenting the detailed data, perhaps a brief description of the bean cooker is in order. I request the indulgence of those who have heard the cooker described one or more times. The design allows each bean in the sample to be cooked in exactly the same manner. The cooker consists of 100 units. Each unit includes a holder for a single bean and a plunger. The small rod on the lower end of the plunger rests on the bean during the cooking. When the bean acquires a cooked texture, the rod suddenly drops. The report of the Sixth Annual Dry Bean Conference contains a picture of the cooker.

During a cooking run the lower portion of the cooker, which holds the beans, is lowered into the cooking water. A cooking run is made by observing the time required for the plungers to drop. Plotting the percent cooked versus the cooking time gives an S-shaped curve as shown in Figure 1 for pinto beans.

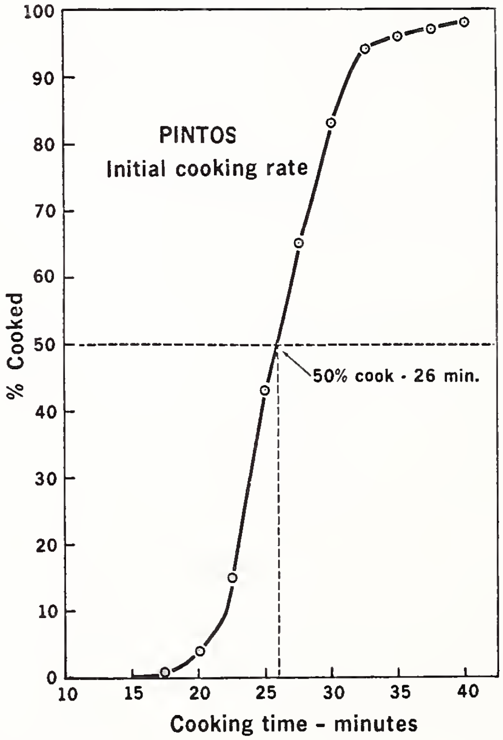

Figure 1. Typical plot of results of cooking test on a sample of pintos.

The most accurately defined point on a curve of this nature, according to statisticians, is the time for 50% cook. For this reason the minutes for a 50% cook will be given as a measurement of the cooking quality of a sample. I would like to emphasize this 50% cook value, since it is the basis for comparing relative cookability of samples.

Material. The beans used were obtained directly from the growing areas. Each variety was divided into five sublots and their moisture content adjusted by mild drying or storing in a high-humidity cabinet as required. Samples of each moisture level were stored at 70° and at 90°F. Table 1 shows moisture values.

Table 1.--Varieties and moisture contents

	Moisture, %	Approx. R.H., %
Pintos	6.5	11
	8.1	25
	10.2	43
	13.3	63
	14.4	70
Sanilacs	8.1	25
	10.6	49
	11.5	55
	13.3	63
	14.2	68
Large Limas	8.0	25
	9.9	40
	11.4	53
	12.3	58
	13.3	63

Experimental results. Results for the three varieties show the same pattern. Since time will not permit me to show all the results, I will select certain data to illustrate the changes that occurred. Figure 2 shows the results for pinto beans stored 9 months at 90°F. The two higher-moisture samples showed a very large increase in the time it took to cook them and the three lowest moisture samples showed very little change. Figure 3, again for pinto beans, shows the rate of change at 70° and 90°F. You will note the beneficial effects of both low moisture and reduced temperature.

As this experiment progressed, we became curious to learn how long the low-moisture samples would retain good cooking qualities. They were appraised after two years and again after three years. Results for pintos stored at 90°F. are shown in Figure 4. These results illustrate most vividly the value of low moisture content for maintenance of good cookability in long storage. Figure 5 shows the result for sanilac beans stored at 90°F. Again the lowest-moisture samples cooked quickly after three years' storage. Similar values for large lima beans are summarized in Figure 6. The values for limas are strikingly similar to the values for sanilacs and pintos; the lowest-moisture samples showed minimal change.

As frequently occurs in research, the results of one experiment illustrate the need for information the first experiment did not provide. For example, the first experiment did not tell us to what extent high-moisture beans would change

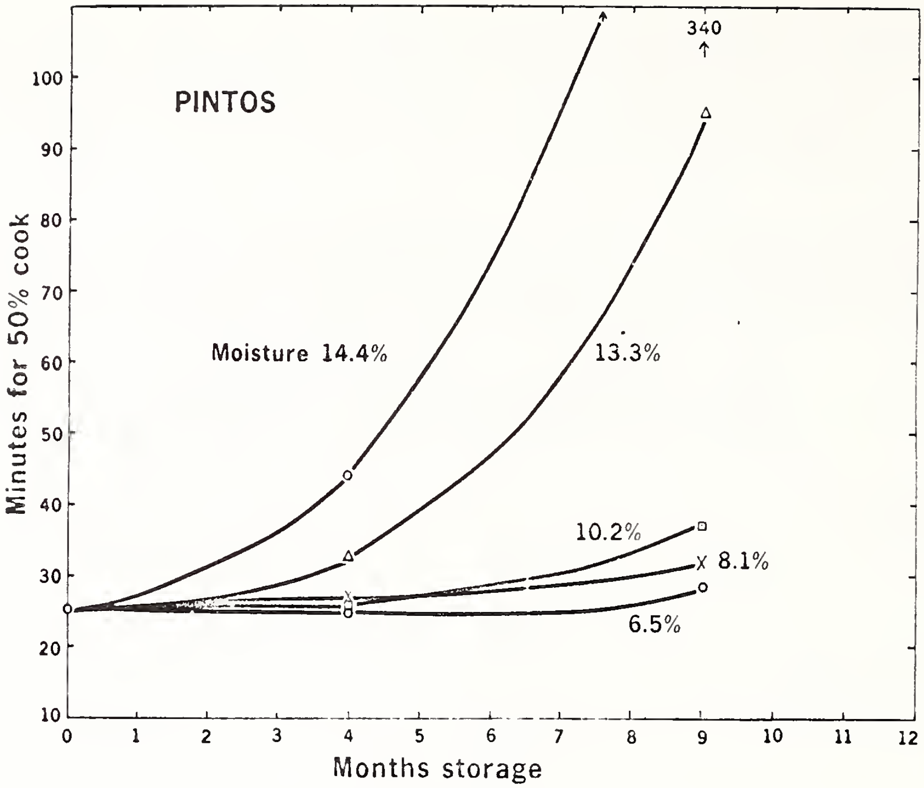

Figure 2. Cooking-test results on pintos held at varied moisture contents.

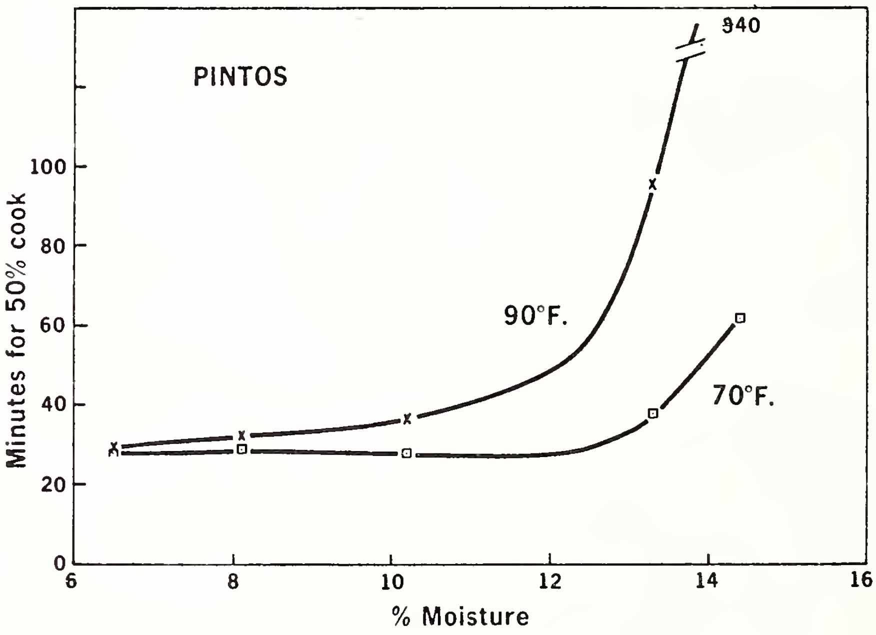

Figure 3. Results with moisture content plotted against time for a 50% cook.

if stored below 70°F. and since the rate of change at 70°F. was much slower than at 90°F., it becomes important to know if significant changes would occur in high-moisture beans if they were stored at temperatures more comparable to

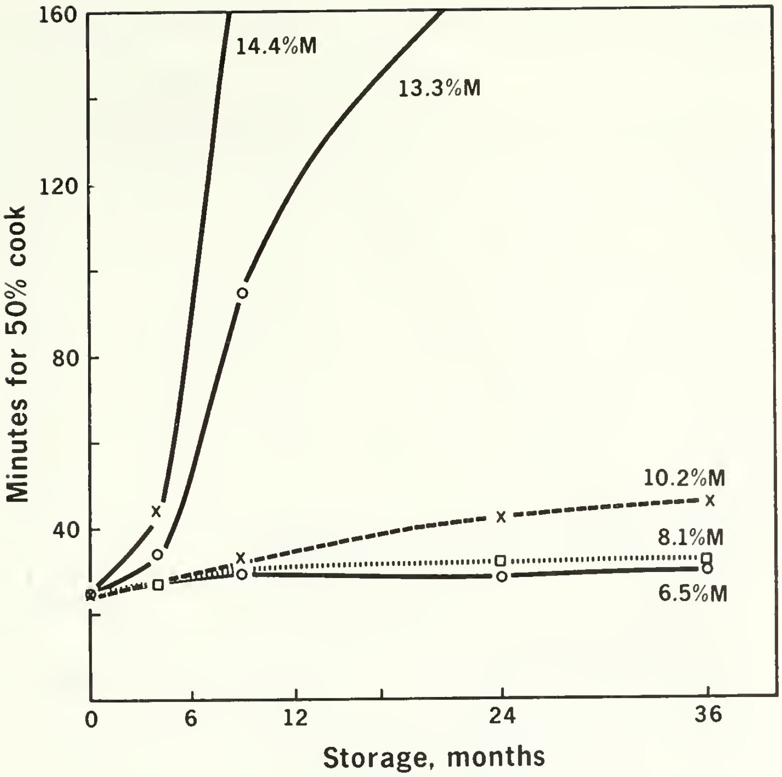

Figure 4. Three-year comparison of pintos with varied moisture content.

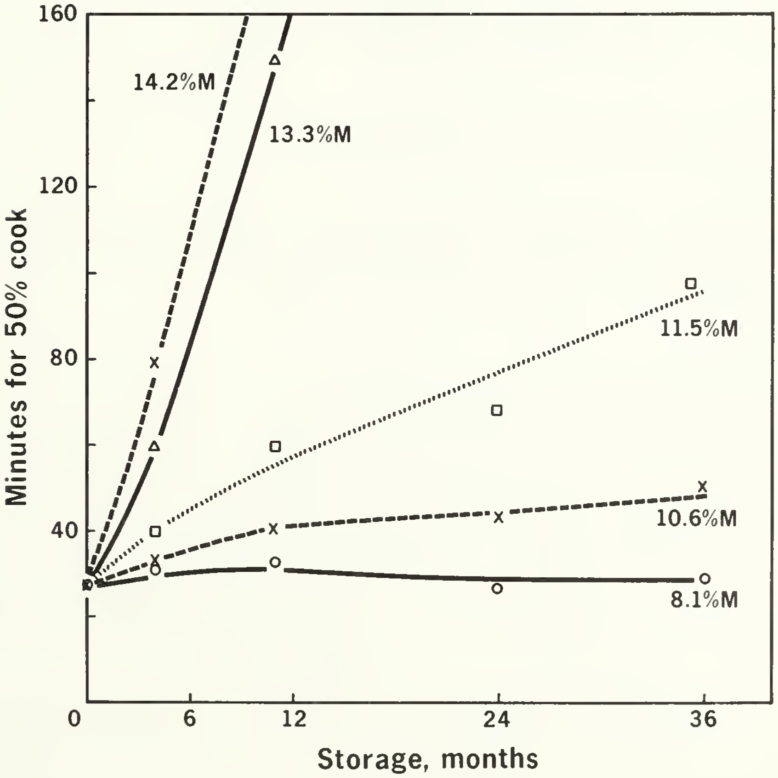

Figure 5. Three-year comparison of sanilac beans with varied moisture contents.

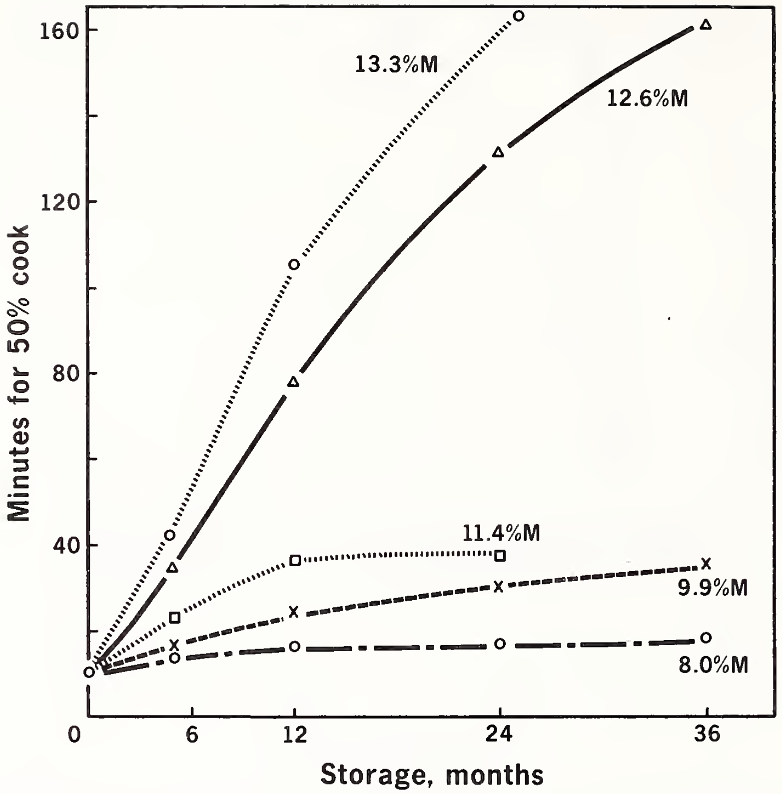

Figure 6. Three-year comparison of large lima beans with varied moisture contents.

winter warehouse conditions in cold climates. To obtain such information we started a second experiment about a year ago.

The same varieties were used in the second as in the first experiment, but they were adjusted to somewhat higher moisture and stored at lower temperatures as shown in Table 2. In order to have some overlapping conditions in the two experiments, samples were stored also at 70°F.

Appraisal of the high-moisture samples stored at 70°F. started after one month's storage and continued at frequent intervals (Table 3). Several interesting comparisons can be made. The 15.5%-moisture sample showed significant increases in cooking requirements after one month at 70°F. and required twice as long to cook after four months at 70°F. as it did at the start. Lowering the moisture content from 15.5% to 14.9% reduced the rate of change to one-half the rate in the higher moisture sample. These relative rates may be seen by comparing the one- and two-month values, and the two- and four-month values. Again the rate of change of the 13.1%-moisture sample was one-third the rate of the 15.5%-moisture sample as shown by the six-months values.

The loss of cooking quality at 55°F. (Table 3) was one-third that at 70° in the case of the 15.5%-moisture sample; you can see this by comparing the two-months and six-months values for this sample. These data indicate that reducing the moisture content six-tenths of one percent is as effective as lowering the temperature 15 degrees. No significant changes occurred in the beans stored nine months at 40°F. Sanilac and pinto beans are showing results similar to those of large limas.

Table 2.--Varieties, moisture contents, and storage temperatures used (indicated by x)--1963 harvest

Variety	Moisture content %	Storage temperature 40°F.	55°F.	70°F.
Pintos	8.2	--	--	x
	10.3	--	--	x
	12.2	x	x	x
	13.9	x	x	x
	16.0	x	x	x
Sanilacs	9.0	--	--	x
	10.7	--	--	x
	12.9	x	x	x
	14.7	x	x	x
	16.7	x	x	x
Large Limas	8.9	--	--	x
	11.3	--	--	x
	13.1	x	x	x
	14.9	x	x	x
	15.5	x	x	x

Table 3.--Effect of storage temperature and moisture content on cooking time

	Moisture content (%) of large dry lima beans				
Months stored	15.5	14.9	13.1	11.3	8.9
at 70°F.	Minutes for 50% cook				
0	--	--	14	--	--
1	18	--	--	--	--
2	22	18	--	--	--
4	29	23	--	--	--
6	39	29	22	17	16
9	51	35	--	--	--
at 55°F.					
6	22	17	16	--	--
9	26	--	--	--	--

Discussion. Results of these experiments appear to be more important for beans sold at retail than for beans to be processed. With present emphasis on convenient foods and the increasing demands for quick-cooking beans, it would appear valuable to preserve for the homemaker the cooking quality of freshly harvested beans. Beans for processing could perhaps demand somewhat longer cooking before becoming objectionable, since the processing time for safety is usually more than adequate to cook freshly harvested beans. Large changes in cooking quality, however, can affect processing quality. Bigelow and Fitzgerald of the National Canners Association reported that after the product is known to be sterile, it is often necessary to continue heating to soften the beans.

Variation in moisture and difference in storage temperature could disturb uniformity in processed quality. The present experiment will continue in order to learn how effectively the lower temperatures of 40° and 55°F. reduce the rate of loss in processing quality of high-moisture beans. We are also interested in learning what chemical or physical changes are affecting cooking quality of beans.

EFFECTS OF HYDRATION IN SALT SOLUTIONS ON COOKING RATES OF LIMA BEANS

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The preparation of lima or other dry beans and peas generally involves hydration in water for 12 hours or longer and extended cooking. Brief immersion in hot water and other shortcuts have been suggested for accelerating hydration prior to cooking. However, unfavorable modifications of texture and flavor have been observed with boiling water. Aside from economic considerations, satisfactory quick-cooking bean products should meet the following specifications: the processed bean should be similar in appearance to the original dry bean; preparation time should not exceed 30 to 40 minutes; the cooked, processed product should appear and taste like beans prepared in the conventional manner; and the processed beans should be stable for at least 6 months under ambient conditions.

It was reported previously that changes in the electrophoretic mobility of bean proteins appeared to be associated with cooking rates of dry lima beans. Therefore studies were conducted using various salt solutions designed to dissociate, disperse or peptize bean proteins during hydration.

The automatic-recording shear press was employed to estimate the rates of seed coat and cotyledon softening during cooking of hydrated large lima and other dry beans. Tenderization rates of seed coats and cotyledons were independent of each other and dependent upon the bean variety, its time-temperature history, moisture content, and cooking technique. Organoleptic acceptability was related to shear pressures and work functions. Softening of seed coats from freshly harvested, large dry lima beans was slower than for the cotyledons. Slower softening rates were obtained for both tissues in older beans or lima beans stored above or below an optimum moisture level at elevated temperatures. The absolute and relative rates of seed coat and cotyledon softening varied broadly with other bean varieties.

Vacuum hydration of whole beans with salt solutions modified the softening rates of seed coats and cotyledons independently. Chelating agents such as the alkali metal salts of tripolyphosphate, pyrophosphate, and ethylenediaminetetra-acetate reduced and reversed relative softening rates. After hydration with salt solutions, beans were dried under mild conditions without serious modification of their appearance. The dried products, which included large lima, baby lima, pinto, red kidney, pink, small white, red, blackeye, and Great Northern beans; lentils; soybeans; and whole green peas, rehydrated and cooked within 25 to 50 minutes and equaled or exceeded conventional products in flavor, appearance, and stability.

THE ISOLATION AND TESTING OF THE FLATULENCE FACTOR IN GAS FORMING FOODS

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In our studies we are feeding test meals of cooked dry beans to human subjects and measuring flatus with a simple portable apparatus worn by the subject. With this technique we can evaluate our attempts to isolate and identify the flatulence principle in dry beans and also conduct related studies such as comparison of other gas-forming foods and testing the effects of food additives or drugs on flatus formation. Each study is designed to help answer the question, Why do dry beans cause gas?

Our results agree with the finding of Dr. Steggerda, University of Illinois, and other workers that when an average man eats cooked dry beans, his egestion of rectal gas rises 10- to 20-fold. This increase is due primarily to increases in carbon dioxide and hydrogen gas. Almost all of this increase occurs during a 2- to 3-hour period about 6 hours after the bean meal is eaten. Corresponding to this period of increase, hydrogen gas in the breath rises and falls in a similar pattern. Accompanying increased gas egestion is an uncomfortable feeling variously described as fullness, sick stomach, and intestinal rumblings. The brief descriptions of progress which follow will include the separate pieces of information upon which we have now formed a tentative general theory of the origin and mechanism of formation of flatus in human subjects.

As we have stated, carbon dioxide and hydrogen are the major components of flatus during the period of peak production of gas. Carbon dioxide, other than a smaller contribution from fermentation by the intestinal microflora, is produced in the small intestine from the stomach acid neutralization of the bicarbonate moiety of the various basic digestive secretions. In the presence of bean digesta, which evidently contains a principle that interferes in some manner with the normal transport of carbon dioxide into the blood, the carbon dioxide passes on down the gut to become the major component of the flatus instead of being eliminated from the body in normal respiration. This carbon dioxide interference can be one or a combination of several mechanisms: inhibition of the carbonic anhydrase enzyme; gut wall irritation; foam formation; vascular constriction; or an increase in intestinal motility. At the present time we are examining the flatulent chemical fraction for a carbonic anhydrase inhibitor as the most likely cause of flatulence.

The second largest contributor to flatus is hydrogen gas. Based upon preliminary experiments, hydrogen seems to be formed by some as yet unidentified micro-organism, other than a common anaerobe, in the small intestine, which utilizes as substrate the galactose-containing polysaccharides from the bean which pass the human stomach unchanged. Hydrogen, in contrast to the enzymatically catalyzed transport of carbon dioxide, is eliminated in respiration by simple physical considerations depending upon the individual efficiency of respiration. We have found this efficiency to vary within wide limits among our human subjects.

Both oxygen and nitrogen in flatus probably arise from swallowed air. It has been estimated that the average person swallows ten times the volume equivalent of air when drinking a glass of milk. Since little of the nitrogen is to be absorbed in the gut, it must pass as flatus. When a subject is in a nonflatulent condition, the largest flatus component is nitrogen, followed by oxygen, methane, carbon dioxide, and hydrogen in order of rapidly decreasing percentage composition. In about half of our subjects methane and/or hydrogen was absent during a nonflatulent period. After a meal of beans, this order is reversed. Hydrogen or carbon dioxide is the largest, followed by methane, nitrogen, and oxygen in decreasing order. Methane, nitrogen, and oxygen fall rapidly in percent composition as the peak flatus production is approached and rise again, as the peak passes, to their "normal" nonflatulent levels. During a peak flatus production period, the ratio of nitrogen to argon, another nonactive gas metabolically, was determined by mass spectrometry and found to be not significantly different from the ratio of nitrogen to argon in air. Methane, which occurs in about half of our subjects in detectable amounts, probably is produced by the anaerobic microflora of the colon and is simply swept out by the sudden passage of the relatively large volumes of carbon dioxide and hydrogen.

<u>Pattern of flatus egestion</u>. As we reported at the Sixth Bean Conference in Los Angeles, the egestion of flatus by human subjects follows a well defined and predictable pattern (Figure 1). After a bean meal is eaten by the subject,

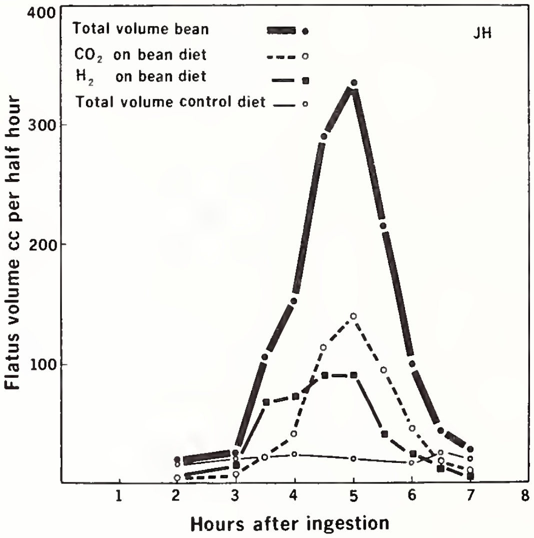

Figure 1. Flatus composition and volume, 100 grams

no elevation occurs in the volume of flatus above the normal level for 3 to 4 hours; then, quite suddenly, the rate of flatus egestion increases to a maximum between 5 and 6 hours and falls back to a base line or "normal" value by the end of 7 to 8 hours. Of special significance in flatulence studies is the 3- to 4-hour delay after ingestion of a bean meal, during which the flatus egestion on a gas-forming food would appear to be the same as that on a nonflatulent meal. This, plus the fact that there are individuals who, because of high respiration efficiency, can eliminate gases of flatulence by way of the breath, has misled many research workers.

This graph (Figure 1) serves as both a qualitative and a quantitative tool by which we can measure human flatulence. Qualitatively, the appearance of a well defined peak in flatus production indicates that the food eaten by the subject about 6 hours previously was flatulent. No such peak appears in the pattern of flatus egestion following a nonflatulent meal. The sudden appearance or increase in the hydrogen component of flatus of the subject indicates that he has eaten a flatulent food. Quantitatively, the "area under the curve," representing the peak flatus egestion period, or the total volume of flatus passed by the subject for the 3-hour peak egestion period, can be used to compare different gas-forming foods, treated or processed foods, or experimental bean extracts. The timing and shape of the curve representing flatus egestion will be significant later in the elucidation of flatus formation and elimination.

Individual differences in flatus composition and volume. The total volume, time of peak egestion, and flatus composition vary for individual subjects eating equivalent experimental bean meals. The most outstanding difference in flatulence reaction between individuals, total flatus passed (Figure 2) is probably not due primarily to differences in volume of gas produced in the gut but rather to a physiological difference in the ability of the individual to transport the gases through the intestinal wall into the blood, and thus eliminate them through the lungs. The amount of flatus passed by an individual is inversely proportional to his degree of reaction to the principle in the bean which blocks his natural processes of gas absorption across the intestinal wall, and his "respiration efficiency." During the testing of subject GN, a relatively low flatus producer (Figure 2), two increases in total flatus volume occurred which may be significant to our understanding of bean flatulence. Once during

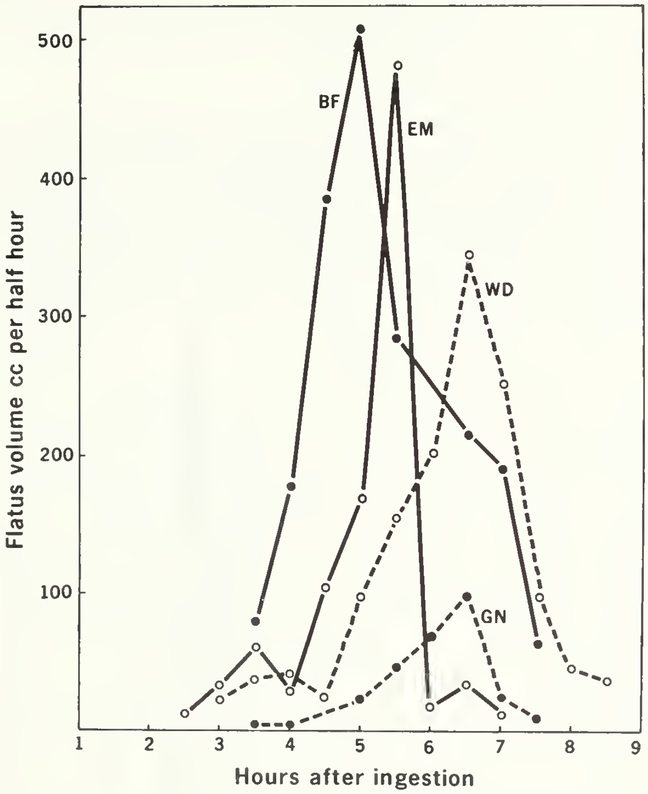

Figure 2. Individual flatus production California small white beans, 100 grams.

a period of severe lung congestion his total flatus volume increased five-fold. We interpret this as a reduction in his natural high respiratory efficiency.

Another increase occurred when the weight of the test meal was doubled. We would like to ascribe this flatus volume increase to an increase in amount of gas-transport blocking principle from the larger bean meal and an increase in the fermentable, galactose-containing polysaccharides, thus furnishing more substrate for greater hydrogen production by the microflora of the small intestine. Here two "threshold principles" are operating: one requires a sufficient degree of interference with carbon dioxide transport before elimination through the lungs gives enough in rate to prevent carbon dioxide from passing on down the gut; the other is excess in rate of hydrogen production by intestinal microflora over the individual's specific and "set" physiological rate of hydrogen elimination through respiration. If we may continue in this speculative line of thought, as if the problem of flatulence from dry beans were not already complex enough, the magnitudes of these thresholds are probably independent and vary from person to person. Let us only hope that they are not also changing continuously within the same person.

For any test subject, the composition of flatus from eating a nonflatulent food is almost constant over the seven-hour test period of flatus measurements. However, after the usual delay following a flatulent meal, the composition of the flatus changes rapidly. In most subjects (Figure 3) as the

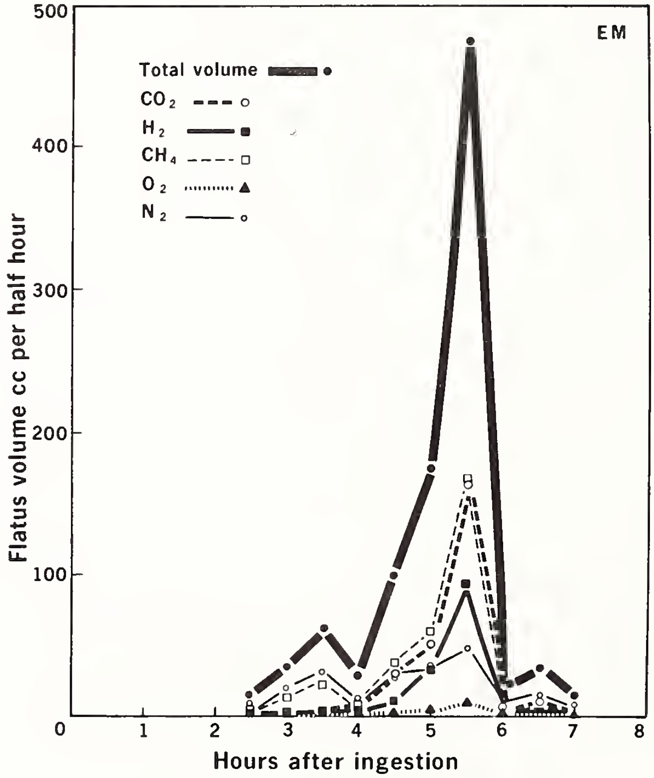

Figure 3. Composition of flatus California small white beans, 100 grams.

peak of flatus egestion is approached, the percentages of carbon dioxide and hydrogen increase, while the percentages of oxygen, nitrogen, and methane may fall to low values. This suggests that carbon dioxide and hydrogen are the only two gases being increased by a meal of cooked dry beans. The other gases (oxygen, nitrogen, and methane) evidently do not contribute significantly to the sudden onset of discomfort. Their increase in volume at peak egestion results from their being swept out of the gut simultaneously by the rapid evolution of carbon dioxide and hydrogen.

Several test subjects have shown significant differences in flatus composition. Subjects EM and BF (Table 1) are methane gas producers, while WD produces no detectable methane on either a flatulent or a nonflatulent diet. From the findings of other workers, our general population is apparently divided about half and half in respect to methane production. The methane producers probably have a larger number of anaerobes in their microflora. Another striking difference in flatus composition, is in the percentage of hydrogen gas. As can be seen from Figure 4, all subjects produce significant volumes of hydrogen

Table 1.--Composition of flatus at peak gas production

Subject	CO_2	H_2	CH_4
EM	33	19	29
WD	15	45	--
BF	10	44	11

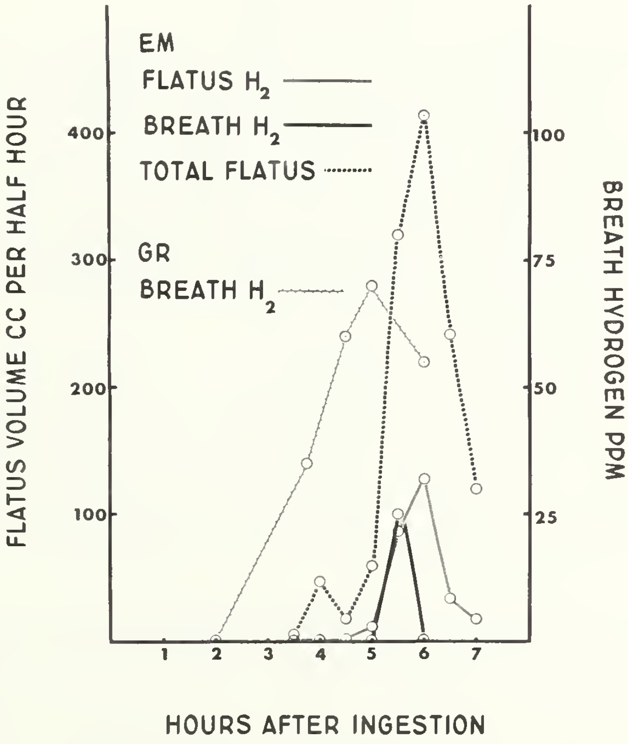

Figure 4. Breath hydrogen, flatus hydrogen, total flatus.

following a bean meal. In fact, as already mentioned, the sudden appearance or increase in volume of hydrogen gas in the flatus can be taken as a reliable indication that the food eaten about six hours previously was flatulent.

Breath hydrogen measurements. After a human subject eats a bean meal, the proportion of hydrogen gas in the breath rises (Figure 4) in a pattern very similar to that of the increase in flatus egestion. The breath hydrogen peak precedes by a few minutes the peak in flatus egestion. The rate of elimination of hydrogen from the body in the breath evidently varies within wide limits between individuals. As in the case of hydrogen, when the gas production in the intestine exceeds the specific respiratory efficiency of the individual in eliminating it from the lungs, the excess gas is then eliminated from the body as flatus. For example, during our tests, one of our subjects, GR (Figure 5) after ingesting a No. 2 can of pork and beans, passed only a trace of flatus and at the same time passed a significant amount of hydrogen in his breath. While by comparison, subject EM (Figure 5), on an identical can of beans, passed a large volume of flatus containing a large percentage of hydrogen gas and was found at the same time to have only a trace of hydrogen gas in the breath. Our tentative theory would explain that subject GR had a very high respiratory efficiency and thereby was able to eliminate most of the gas by diffusion into the blood and respiration, whereas EM, with a correspondingly low respiratory efficiency, at least for hydrogen, developed a flatulent condition. Of further interest here is the fact that later subject GR ate 1-1/2 No. 2 cans of beans and became flatulent. Thus, he has a threshold in respiratory efficiency and in this case the rate of gas formation exceeded the rate of diffusion and respiratory elimination and the excess gas was eliminated as flatus.

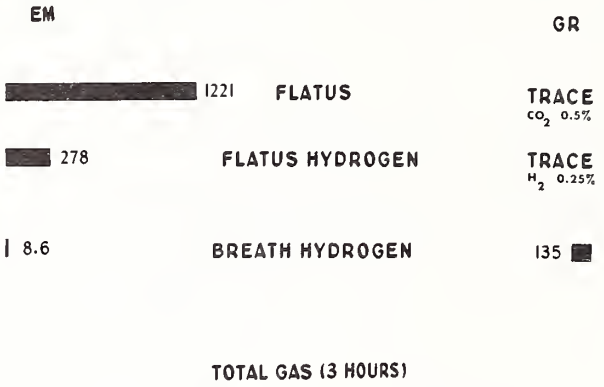

Figure 5. Breath and flatus hydrogen, two subjects, after consumption of a no. 2 can of pork and beans.

An exploratory experiment on the effect of exercise on the production of flatus from a bean meal was performed with a subject whose gas volume was known under ambulatory conditions. When the subject ran for 15 minutes of each of the 30-minute flatus-measurement periods, thereby raising his normal breathing rate of 12 respirations per minute to 42, the resulting flatus volume was only 60% of the volume collected from this subject during an ambulatory period. Here again we have an increase in respiratory elimination of gas through increased ventilation due to exercise, thereby eliminating the intestinal gases through the lungs before they become flatus.

In evaluating the flatulent condition in human subjects, the measurement of breath hydrogen is a valuable supplemental tool, as will be a simultaneous measurement of skin and blood gases that we are now preparing to make. The measurement of breath hydrogen (and breath methane) alone cannot be taken as a sole criterion of a flatulent condition, since the ingestion of any simple sugar will result in elevated breath hydrogen without a corresponding increase in flatus volume. The major part of the hydrogen gas from a bean meal is produced in the small intestine by micro-organism fermentation of bean sugars and especially the poorly utilized (by the human subject) galactose-containing polysaccharides stachyose and raffinose. In our laboratory, four-hour incubation of stachyose at body temperature, with fresh human stomach juices, failed to produce any chromatographic evidence of breakdown of this sugar. Hence, the 2 to 5% of free sugar in the bean passes the human stomach to become available as a microbial substrate in the small intestine. This incubation was done in connection with feeding studies made with the major bean sugars, stachyose and raffinose, to five human subjects to test the flatus-forming characteristics of these sugars after they were found to be present in the active fraction isolated from cooked dry beans in our isolation and identification studies. The level of hydrogen in the breath went up in all subjects after ingesting the bean sugars; however, no increase in flatus volume could be demonstrated. Therefore, these sugars contribute their share of hydrogen formation in the small intestine after a bean meal is eaten; but unless sufficient hydrogen is suddenly produced to overwhelm the mechanism of absorption into the blood, or is in addition to relatively large volumes of other flatus gases, a flatulent condition will not result.

Peristalsis theory of flatulence. For sixty years many scientific references and medical textbooks have mentioned one simple physiological mechanism which may be responsible for the formation of intestinal gas. Theoretically some substance in the bean causes an increase in gut motility which moves the intestinal contents along at an accelerated pace. Normal absorption rates are reduced to such an extent that unabsorbed nutrients are available for fermentation by micro-organisms in the lower bowel. Thus, not only would the gases of digestion not be absorbed but to these would be added the fermentive gases of the micro-organisms, forming an appreciable volume of gas.

To test this increased motility theory of flatus formation, we measured the motility pattern in human subjects following our standard bean meal and compared it with that following a nonflatulent rice meal. To measure motility, the human subject swallowed a small transistorized, battery-powered, radio transmitter, whose frequency was modulated by the movement of a ferrite core attached to a rubber diaphram, which was sensitive to changes in intestinal intraluminal pressure. Since the small intestine is the area of higher motility and absorption, it was considered the most critical area to measure. The "gastric radio" was suspended in mid-ileum, as indicated by X-ray, on 1.5 yards of suture thread and anchored to one of the subject's front teeth.

Recordings for six hours after ingestion of the bean and rice meals were very similar in frequency of occurrence and magnitude of the pressure waves which reflected intestinal motility. The strongest contractions, represented by pressure peaks of 40 to 60 millimeters of mercury, occurred 2 to 4 hours after ingestion and were interpreted as "hunger pangs" since they could be made to disappear immediately by feeding the subject a cup of coffee or a candy bar.

Thus, beans probably do not increase intestinal motility and some other explanation for the formation of flatus must be sought.

In connection with the work with the "gastric radio," barium sulfate was mixed with the bean test meal to make it radio-opaque to X-rays, thereby making it possible to follow the progress of the bean meal through the gastrointestinal tract (Figure 6). Its position at any time after ingestion of the test meal could then be related to the intestinal motility, as transmitted by the gastric radio, as well as to the pattern of egestion of flatus. The most significant single observation to come from the series of X-ray pictures was that the bean meal was just entering the ascending colon of the test subject at the time the hydrogen component of the breath and the volume of egested flatus was beginning to rise. In other words, the major components of flatus, hydrogen, and carbon dioxide, must already have been formed in the small intestine.

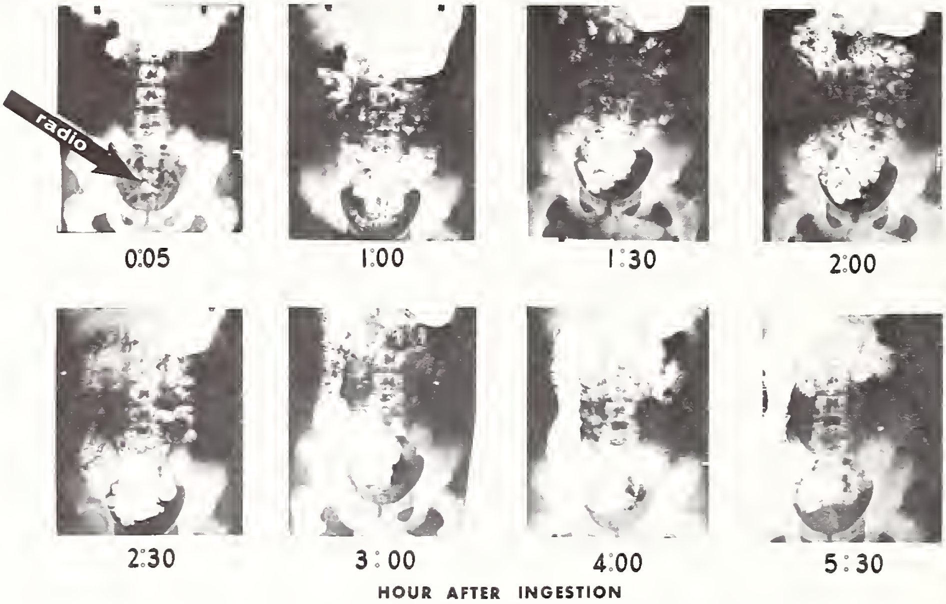

Figure 6. Progress of bean meal through intestinal tract.

Effect of drugs on bean flatulence. Vioform (iodochlorhydroxyquinoline, Ciba) is a drug long prescribed for amebic dysentery. A report by Professor Steggerda (see report of Sixth Bean Conference) that this drug had a marked effect on the flatulence from beans prompted us to determine the effect of this drug on the pattern and composition of flatus production. The general effect of Vioform was to reduce, but not eliminate, the volume of total flatus from the test bean meal (Figure 7). However, far more significant were the changes in composition of the flatus of the subject after administration of Vioform, two 250-mg. tablets, three times during the day preceding and again with the test meal of 100 g., dry weight of California small white beans. The volume of carbon dioxide in a three-hour collection of flatus was reduced 45%. Since most of the carbon dioxide in flatus arises from the basic digestive secretions, this reduction probably reflects the elimination of the contribution to the total volume of carbon dioxide of fermentation by the intestinal microflora. The methane volume rises 63% on beans plus Vioform. This increase in methane production had been predicted, since it had already been established that the total

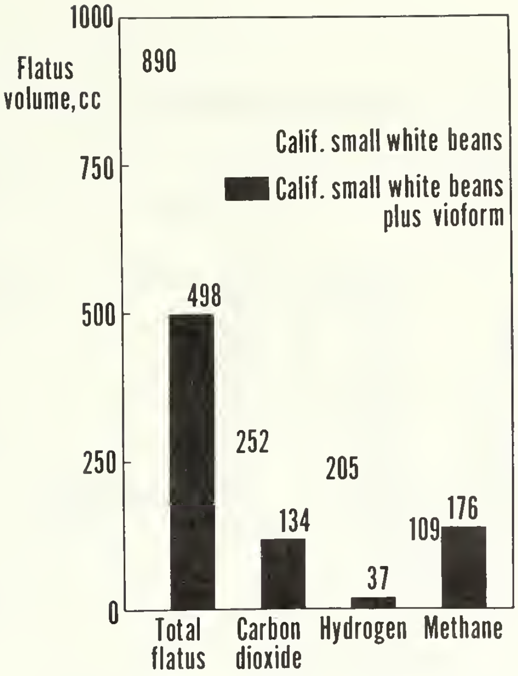

Figure 7. Effect of Vioform on bean flatulence.

population of anaerobic organisms increases one- to four-fold at this dose level of Vioform. According to our tentative theory, methane is produced in the colon or lower bowel by anaerobic fermentation; and since its volume constantly falls during the flatulence period, it is merely swept out by the sudden passage of the relatively large volumes of hydrogen and carbon dioxide.

The most dramatic single effect of Vioform is upon the hydrogen component of flatus. The hydrogen produced from the bean-Vioform test meal is reduced 82% below that produced by the same subject on a bean meal. This reduction and the location of the bean meal in the gut at the time hydrogen begins to appear in the flatus suggests that the hydrogen component of bean flatulence is produced in the ileum or small intestine by other than a common anaerobic micro-organism.

To establish the origin of the component gases of flatus, we plan to examine the effect of other drugs on the volume and composition of flatus from a bean meal. In addition, we may utilize a relatively new biological tool, the "germ free" animal, whose flatus on a bean meal should contain no gases due to fermentation of micro-organisms.

<u>Isolation of the flatulence factor from dry beans</u>. Our original problem as well as our continuing major research effort is the systematic isolation of the flatulence principle from cooked dry beans through successive physical and chemical treatments. As each separation is made, the resulting fractions are fed to human subjects and the resulting flatus measured by our assay technique. We then further examine that bean fraction which the assay results indicate to contain the major part of the flatulence activity. By tracing the flatulence activity with our human assay technique, we have found (Figure 8) that the activity is extracted from cooked beans with 60% ethanol, will dialyze through

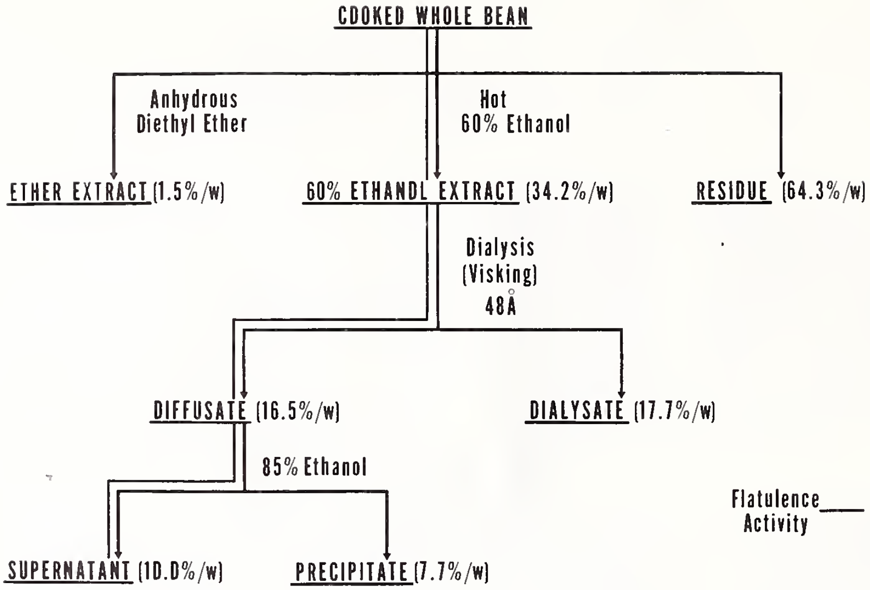

Figure 8. Extraction of flatulence principle.

cellulose sausage casing, and is soluble in 85% ethanol, in this order. The next step will be passage of the flatulent bean fraction through a cation-anion exchange resin to separate the chemical compounds into those carrying an electrical charge and the neutral or uncharged molecules. The most significant inference from this separation procedure is that the principle in dry beans responsible for flatulence in man is low in molecular weight, perhaps even below 10,000. Thus to date we have eliminated the protein, starch, complex polysaccharide, and lipid fractions of the dry bean.

Chemical additives for reduction of bean flatulence. A number of people have submitted various "grandmother's recipes" for cooking beans which were asserted to prevent gas. We have prepared our test meal of California small white beans by many of these procedures. These have included cooking with sodium bicarbonate, ginger, castor oil, and phosphates. To date, no chemical or physical method has significantly reduced the volume of flatus collected after one of our subjects has eaten the test bean meal (Figure 9). Further, other workers have found that such physical operations as grinding, high pressure homogenization, high-temperature cooking, prolonged baking, or extended soaking time do not appreciably affect the flatulence of dry beans.

Comparative study of the flatulence of other foods. Of all the questions we are asked, the most frequent is "Which foods are really flatulent?" Especially doctors of medicine and nutritional scientists are concerned, since there is either no information available or the statements on gas formation are in sharp conflict. In the course of our work with dry beans, we have tested other gas-forming foods using the same assay technique and some comparisons can be drawn (Table 2). Within close variety relationships, the degree of flatulence from dry beans seems to be similar; however, as the variety changes, the degree

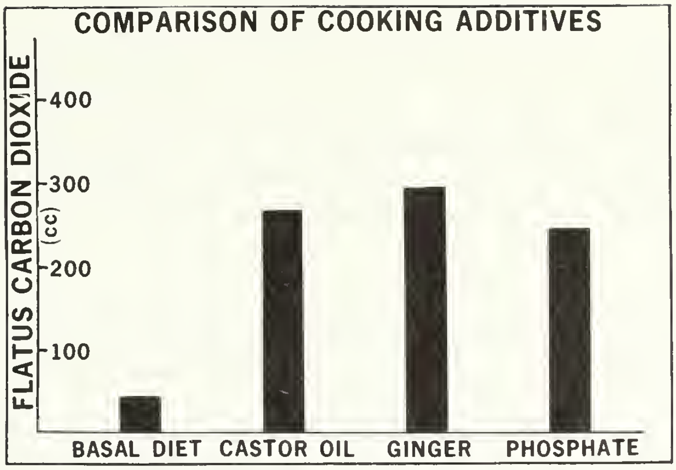

Figure 9. Comparison of cooking additives.

Table 2.--Flatulent foods.

380 g. (wet)	Total flatus (3 hrs.)
Bean	cc.
California small white	1050
Red kidney	1120
Lima, dry	535
Lima, frozen	141
Cabbage	
Cooked	212
Raw	460
Onion, cooked	587
Apple, raw	214
Basal diet	92

of flatulence varies. For example, the lima bean is about half as flatulent as the California small white. It is interesting that the green frozen lima bean produces relatively little flatus in our human subjects compared to the mature dry lima bean. Among other notable gas-forming foods are cabbage and onions, which are only about half as flatulent as dry beans. It is interesting that the pattern of the egestion of flatus from a cabbage meal is similar to that for beans. In the case of cabbage, cooking seems to reduce the degree of flatulence. The volumes of flatus for the cooked and raw cabbage were collected from the same subject for the same head of cabbage. As further data are collected, a final list will be compiled with a coefficient of flatulence for each food tested to enable members of the medical and nutritional professions to compile diets and institutional menus with greater effectiveness and confidence.

THE MECHANISM OF GAS PRODUCTION FOLLOWING THE CONSUMPTION OF BEANS

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If one is disturbed by excessive flatulence, it is natural to believe that the cause is due to something he has eaten. Legumes of different types have come to be known as the principal offender. Such food products as onions, sweet potatoes, and nuts of various kinds have also been found guilty by certain people.

It must be pointed out, however, that clinical findings have shown that there are a large number of patients who experience the flatulence distress syndrome without necessarily having ingested any specific type of food. Dr. Ivan E. Danhof from Dallas, Texas, has agreed to our use of his classification of the flatulence distress syndrome that he has tabulated from the examination of a large number of clinical patients. His statement of the types, diagnosis, and symptoms and percentage distribution for each condition is as follows:

No.	Condition	Diagnosis and Symptoms	Distribution
I	Aerophagia	Excessive air swallowing (due to reflex inhibition of the pharengeal sphincter)	20%
II	Stomach acid	Excessive low or high acid secretion	10%
III	Frothing	Hyper mucous secretion (accompanied by abdominal distress)	30%
IV	Hypotonicity (mainly in colon and lower ileum)	Abdominal distention (marked delay in passage through the intestine and colon. Also low rectal balloon pressure and high CO_2 in flatus)	25%
V	Maldigestion	Undigested residue (pancreatic enzymes and high disaccharide concentration in the stools)	15%

As indicated the classification has reference only to pathological conditions that reach the clinician for diagnosis and treatment. It should be pointed out that when bean products are consumed, the presence of the beans or some of the end products of their digestion might have a stimulating influence on the mucosal membranes and musculature of the stomach, intestine and colon to cause a temporary activity similar to that reported above in clinical patients and thus cause a certain degree of the flatulence syndrome. (See DeEds: Report of the Sixth Annual Dry Bean Conference.) Further observations, concerning the effects of bean products on the acid secretion in the stomach, hypersecretion of the mucous membranes, motility, and the digestibility of beans in the gastrointestinal tract, have not been carefully studied and are worthy of investigation.

In practically all of our reports to the Western Utilization Research and Development Division, USDA, Albany, California, with whom we have contracts to study the nature and mechanism of action of dry beans on flatus production, it was pointed out as a definite conclusion that when dry bean products are consumed there does occur a consistent increase in flatulence production and the carbon dioxide present in the flatus collections shows a remarkable increase in concentration (from 10 to 50%) without significant increases in any of the other gases present. In view of the fact that these high concentrations of carbon dioxide could not conceivably come from swallowed air, the blood stream, or mucosal secretions, it was theorized that the logical source could be the pancreatic secretion. This is possible because of the well established high concentrations of bicarbonate present in pancreatic juice. As a result of acute experimentation on animals this hypothesis was proved to be untenable, because when loops of the upper small intestine were isolated and known amounts of bean homogenates were injected into the loop along with the injection of a pancreatic stimulus secretin, there occurred no noticeable differences in gaseous composition of the isolated loop.

Further experimentation has shown that if loops of the duodenum, jejunum, ileum and colon were made, and slurries of beans injected into each loop, a graded response, in gas production, from the duodenum to the colon was observed. This mechanism of gas production could be inhibited by pretreating the animals with a normal therapeutic dose of neomycin and sulfathaledine or Vioform (iodochlorhydroxyquinoline). If microflora cultures were removed from the intestinal loops prior to and three hours following the administration of the bean homogenate, a marked increase in the carbon dioxide occurred in the cultures exposed to the bean homogenate. Further experimentation has shown that the flora responsible is of the anaerobic type which appears to thrive best on the presence of carbohydrates of a low molecular weight. Experiments have shown that the graded response observed in the duodenum and on down to the colon is directly related to the frequency of anaerobic flora present in these segments of the intestine and colon.

These results support the previous observations reported (see Proceedings of Sixth Annual Dry Bean Conference) on the action of mexaform (entobox 20 mg. + Vioform 200 mg. + antrenyl 2 mg.) on inhibiting the production of flatulence in human subjects on high concentrations of dry beans. In that report it was pointed out that the antibiotic Vioform was the responsible agent for inhibiting flatus production.

SENSORY EVALUATION OF CANNED LIMA BEAN VARIETIES

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The standard lima bean has a reputation for distinctive nutlike flavor which sets it apart from all other beans. Because of its unique flavor qualities, it has won a place on menus as the aristocrat of the bean family. This reputation of limas has evolved over the past 75 years during which essentially only one variety has been grown. The California lima bean breeding program is using a wide diversity of genetic variability to produce new varieties with improved agronomic characteristics. The use of new germ plasm has the possibility of introducing new flavor characteristics into the breeding lines, since many of the parents used have flavor and texture noticeably different from those of the commercial variety.

Flavors differing from the standard Ventura are not always easily detectable by a breeder, especially when evaluating advanced lines soon to be released. No work concerning sensory evaluation of standard limas existed prior to this experiment, making it all the more difficult to evaluate new lines. Therefore, the experiment to be reported attempted to answer two questions: can flavor and texture differences be scientifically detected and quantified, and if so, are there noticeable flavor differences between the standard and the lines to be released?

Experimental procedure. Three breeding lines, White Ventura, Bulk 51-11, and Veeh Bulk-20, were compared with the standard variety, Ventura, for flavor and texture. White Ventura is a backcross variety of large limas derived from a backcross program involving the recurrent parent Ventura. The nonrecurrent parent was a large-seeded type with the desired characteristic of suppressed chlorophyll development in the seed coat cells. Bulk 51-11 is a line out of a hybrid bulk population involving three parents (Ventura x Early Market and Ventura x 1-14) which is also a white-seed-coated type. Veeh Bulk-20 is a line out of a bulk population the parents of which are numerous and somewhat more varied than the three parental lines of Bulk 51, and again has the white seed coat character.

Beans of the three experimental strains and standard variety were all new-crop beans grown at the same location. They were canned under commercial standards in No. 2.5 cans in a 2.5% salt solution. For flavor judgment a bean puree of smooth consistency was prepared in a blender by use of a uniform amount of bean juice. Whole beans were used for both shear press and judge evaluation of texture.

A 10-member panel scored the lima bean puree for degree of flavor difference from the reference sample, Ventura. A 7-point scale was used in which 6 represented "extremely different from the reference" and 0 represented "same as the reference." Panel members were asked to give a descriptive flavor comment for each sample. A complete block design was used in which every judge received a control sample, Ventura (labeled reference) and 4 coded samples (the 3 new lines and Ventura). Each judge made one flavor judgment per day for each sample for 10 days. The same 10-member panel scored whole lima beans for texture using a 7-point scale where 7 represented "extremely firm" and 1 "very soft." Texture judgments were made each day after flavor judgments were completed, with different codes on the same four strains.

Flavor samples were served in 50-ml. beakers. Texture samples were served in small aluminum cups, three beans to a sample serving. Flavor and texture were evaluated under red illumination in individual taste booths. The Lee-Kramer shear press was used for mechanical texture determinations. It was modified by attachment of a texture cell patterned after the Cristel texturemeter to the hydraulic ram. As the ram descends at a constant speed, the force required to puncture a 50-g. lima bean sample was recorded on a strip chart. The record provides information on the maximum pounds of force required to puncture the 50-g. sample. Two mechanical texture measurements were made on the four strains each day that the judge panel was in session.

Results and discussion. Average flavor values assigned each sample by the judges for degree of difference from the reference are shown in Table 1.

Table 1.--New variety evaluation--lima beans, 1964

Line	Flavor $\bar{x}$	Flavor $\bar{s}$	Texture $\bar{x}$	Lee-Kramer texture[1] $\bar{x}$
Veeh-20	2.67	1.31	3.75	19.44
Bulk-51	2.44	1.54	3.98	21.73
White Ventura	2.43	1.53	4.23	22.75
Ventura	2.03	1.51	4.31	22.48

[1] Lee-Kramer texture values expressed in pounds force/50-g. sample.

Ventura was judged to be most like itself and Veeh Bulk-20 was judged most different from Ventura. Results of the analysis of variance given in Table 2 show that the ten judges could determine that Veeh Bulk-20 is different from the reference 99 out of 100 times. The large significance attached to the effect of judges can be explained by the fact that some judges consistently used low numbers, while others used high numbers. The variety-times-judge interaction is assumed to be partially a result of inexperience on the part of the panel in sensory evaluation of large lima beans and differing flavor preference by the judges.

Table 2.--Lima beans--new varieties--analysis of variance

Sources of variation	Flavor DF	Flavor Calculated F	Texture DF	Texture Calculated F	L.K. textures DF	L.K. textures Calculated F
Varieties	3	3.68**	3	5.98***	3	24.12***
Replications (days)	9	0.51	9	2.20*	9	7.31***
Judges	9	10.54***	9	19.62***		
VxR	27	.37	27	.97	27	2.19*
VxJ	27	1.64*	27	.58		
JxR	81	.66	81	.99		
Error	243		243		40	
Total	399		399		79	
S		1.38		1.04		1.37
$\bar{x}$		2.39		4.07		21.60
C.V.		57.7%		25.6%		6.34%

*, **, *** mean significant at p = 0.05, 0.01, and 0.001, respectively.

Since the flavor values obtained for each strain were based on the relative rank to an evaluated reference sample, the only real basis for determining differences is by use of paired statistical procedures. This was done and the only significantly different line from Ventura at the 5% level or less was the Veeh Bulk-20.

Table 3 shows the summation of the relative position in which the samples were placed by each judge over the ten days. That is, the first position indicates it was most like the reference and the fourth position would be the sample most unlike the reference. The fact that all strains occupy both first and fourth positions is an indication why such a large coefficient of variability was obtained.

Table 3.--Flavor ranking by the judges relative to the reference

	1st	2nd	3rd	4th	Weighted mean
Ventura (Reference)	5	2	1	2	2.0
White Ventura	6	0	2	2	2.0
Bulk 51-11	1	5	3	1	2.4
Veeh Bulk-20	2	2	2	4	2.8

Descriptive flavor terms used more than twice by the panel to describe any one sample were salty, bland, bitter, scorched, metallic, good, sour, hay, stale, musty, sweet, and flat. When the terms which more or less imply "saltiness" or "bitterness" are pooled together and compared to those terms which imply "blandness," White Ventura and Ventura have a higher percentage of "bitterness." White Ventura had 65% and Ventura 60% of the terms used in the bitterness group, Bulk 51-11 had 49% and Veeh Bulk-20 had only 42%. The significant differences detected with the flavor score can with some assuredness be attributed to the more blandness of the Veeh Bulk-20 line.

Average texture values assigned to each sample by the trained panel and average Lee-Kramer texture values are listed in Table 1. Ventura, the reference sample, and White Ventura were judged the most firm by the panel. Both Bulk 51-11 and Veeh Bulk-20 were assigned a less firm position. The Lee-Kramer values show essentially the same results. A calculated correlation coefficient for the daily rank positions between the panel and the shear press showed that they were correlated at the 1% level.

The analysis of variance given in Table 2 for the panel determinations shows significant panel texture variation due to varieties, days and judges. The significance attributed to judges can be attributed to the fact that some judges used consistently larger numbers than did others. Only the Veeh Bulk-20 line was determined to be significantly less firm from the reference Ventura or any of the other entries. Analysis of shear press data shows the same results for variety significance.

Conclusions. The experimental results show that flavor and texture differences of large lima beans can be detected by sensory evaluation. This is especially shown by the determination that the Veeh Bulk-20 line is significantly different in both flavor and texture from the reference, Ventura. The quantification of differences in texture are more reliable than for flavor, as shown by the lack of judge x variety interaction, the larger degree of significance between varieties, and a lower CV for the texture analysis. The exact flavor differences, if such exist, were not detectable except for the general characteristic of more "blandness" on the part of the Veeh Bulk-20 line. The flavor difference of Veeh Bulk-20 was not determined to be more or less desirable, either of which it could be, nor was it shown to be objectionable. Therefore, Veeh Bulk-20 could still be considered for release assuming it meets all the agronomic qualifications.

GROWTH DEPRESSION OF RATS FED FRACTIONS OF RAW NAVY BEANS

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Rats fed uncooked navy bean flour lose weight and die after about two or three weeks. Evidently this growth depression is caused by a heat-labile toxic substance because when the bean flour was heated in the autoclave for 5 minutes at 121°C. rats fed the flour gained weight, although not at a rate comparable to rats fed the same level of protein furnished by casein. However, when the autoclaved, but not the raw, bean flour was supplemented with methionine to increase the level in the protein from 1.0 to 4.2% it supported growth equal to that of casein. Raw navy beans contain two substances which have been thought may be responsible for the toxicity of raw beans. These are the hemagglutinins and the trypsin inhibitors, both of which are destroyed by heating the bean flour in the autoclave for 5 minutes at 121°C.

The present experiment was carried out to separate the hemagglutinins and trypsin inhibitors by fractionation of the raw bean flour and to determine if the fractions that contain the hemagglutinins are the same ones that depress rat growth. Fractionation was carried out by the procedure of Honavar, Shih, and Liener (Journal of Nutrition 77, 109, 1962) as shown in Figure 1. The beans used contained 24% crude protein (N x 6.25). Fraction F_1 (650 grams) contained 7.37% N (46.1% crude protein), F_2 (65 grams) contained 13.00% N (81.2% crude protein), F_3 (6 grams) contained 12.42% N (77.6% crude protein), F_4 (12 grams) contained 10.23% N (64.0% crude protein), and F_5 (45 grams) contained 9.75% N (61.0% crude protein).

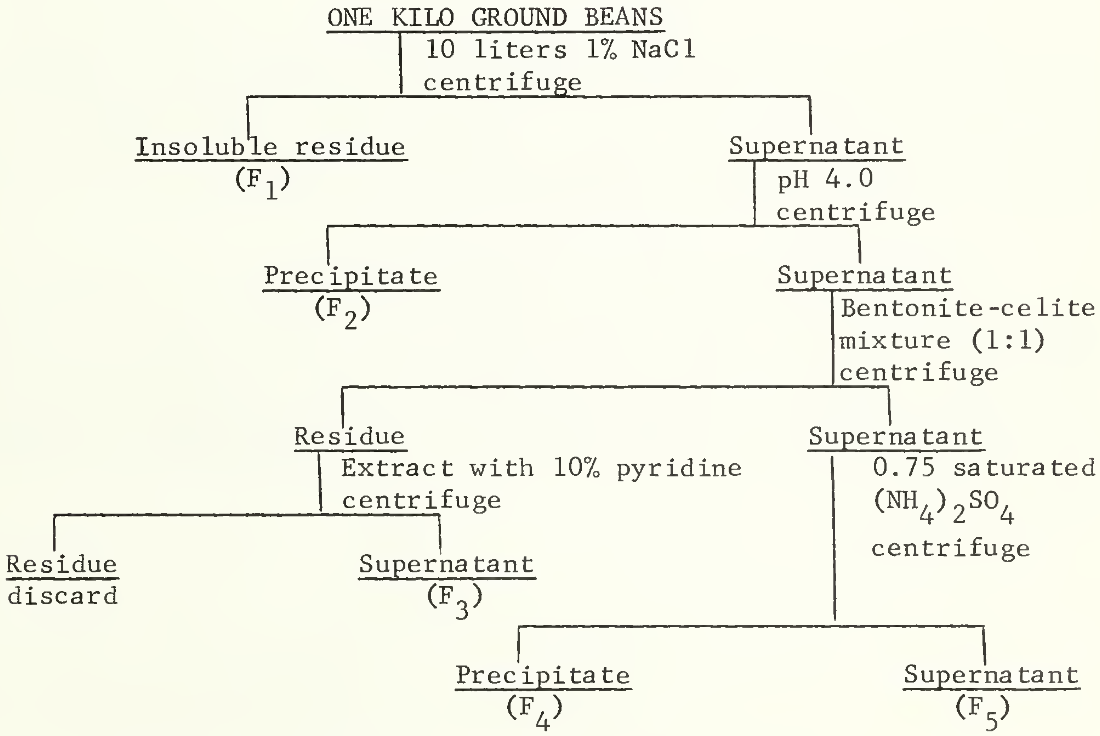

Figure 1. Preparation of navy bean fractions.

Trypsin inhibitor activity was determined by the casein digestion method of Kunitz (Journal of General Physiology 30, 291, 1947) and hemagglutinating activity by the method of Liener (Journal of Nutrition 49, 609, 1953). The results are shown in Table 1. Hemagglutinating activity was concentrated in fractions F_4 and F_5 and trypsin inhibitor activity in fraction F_3. These three fractions comprised 63 grams or 6.3% of the original beans.

Table 1.--Hemagglutinating and trypsin inhibitor activities of various bean fractions

	Hemagglutinating activity HU/mg. protein	Trypsin inhibitor activity TIV x 10^{-3}/mg. protein
F_1	5.3	195
F_2	3.6	113
F_3	0.0	858
F_4	24.1	143
F_5	35.5	122

The basal diet for the rat feeding studies was composed of raw or autoclaved navy bean flour 41.7%, sucrose 30.0%, corn oil 6.0%, Hegsted salt mixture 4.0%, vitamin diet fortification mixture 2.0%, and cornstarch 16.3%. The isolated fractions replaced equal weights of starch or in the case of F_1 of starch and sucrose. The fractions were included in the autoclaved bean diet, and in the raw bean diet as a mixture with the raw beans which was then autoclaved at 121°C. for 5 minutes.

Results of the rat feeding experiment are presented in Table 2. Raw beans depressed growth and caused death within 28 days, but the autoclaved beans supported growth. All of the fractions when included in the autoclaved bean diet significantly inhibited the growth of rats when compared to rats fed the same fraction autoclaved. Fractions were included in the diets at about twice the level that they would be in the beans in a 10% protein diet.

The greatest growth depression, other than that from raw bean flour, came from feeding 1% of fraction F_4. This was one of the fractions high in hemagglutinins, but if one considers the total hemagglutinin or trypsin inhibitor activity added to the ration, the group of rats fed 30% of fraction F_1 received the most, and those fed fraction F_5 received more hemagglutinins than those fed fraction F_4. A toxic material, other than hemagglutinins and trypsin inhibitor appears to be present in raw beans, and this was concentrated in fraction F_4.

Table 2.--Effect of feeding navy bean fractions on the growth of rats

Protein source (navy beans)	Change in weight (g.)	Food intake (g.)	Protein efficiency ratio (PER)
Raw beans	-12.8	88	all died
Autoclaved beans	33.0	220	1.50
Autoclaved beans + 30% F_1	15.7	125	0.53
Raw beans + 30% F_1, autoclaved	61.0	258	0.99
Autoclaved beans + 5% F_2	35.0	240	1.02
Raw beans + 5% F_2, autoclaved	56.3	266	1.49
Autoclaved beans + 1% F_3	13.0	184	0.66
Raw beans + 1% F_3, autoclaved	43.0	247	1.62
Autoclaved beans + 1% F_4	-4.0	94	-0.40
Raw beans + 1% F_4, autoclaved	41.3	271	1.43
Autoclaved beans + 2.5% F_5	17.6	179	0.85
Raw beans + 2.5% F_5, autoclaved	30.6	196	1.35

THE PREPARATION OF BLAND, COLORLESS, NONFLATULENT, HIGH-PROTEIN CONCENTRATES FROM DRY BEANS

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Whole bean flour, fat-free bean meal, and protein concentrates as ordinarily prepared cause flatulence when eaten in appreciable quantity and this has restricted their utilization as foods or food supplements. Legume proteins are particularly unsuitable for inclusion in the diet of children under six months of age. Because of the protein deficit in many areas of the world, there would be an opportunity to expand the market for dry beans if, through research, a way could be found to eliminate the flatulence principle from high-protein bean concentrates or meals.

Based upon the information gained from our attempts to isolate and identify the flatulence principle in dry beans has come a scheme (Figure 1) to produce flatulence-free high-protein concentrates from legumes. This procedure is based upon the fact that the flatulence principle in dry beans has been proved to be low in molecular weight. That is, it will pass through a cellulose membrane in dialysis or remain in the mother liquor after protein precipitation by pH adjustment with acid. Thus, we have a choice of two methods. The first, isoelectric precipitation of the proteins from the carbonate extract, can be brought about by adjustment of the pH from 11 to 4.6, thereby leaving the color, taste, and flatulence principle in the supernatant to be discarded; or second, by dialysis of the carbonate extract during which these factors pass through the membrane into the dialyzing medium which is discarded. Commercially the second method might be made a continuous process of basic extraction, dialysis and spray drying to yield a bland high-protein concentrate. The percentages in Figure 1 give the overall yield for sodium carbonate residue, acid precipitate, and dialyzate and the percentages in parentheses represent the protein in each concentrate. This method has been applied to California small white and lima beans and the percentages in Figure 1 apply to soybeans.

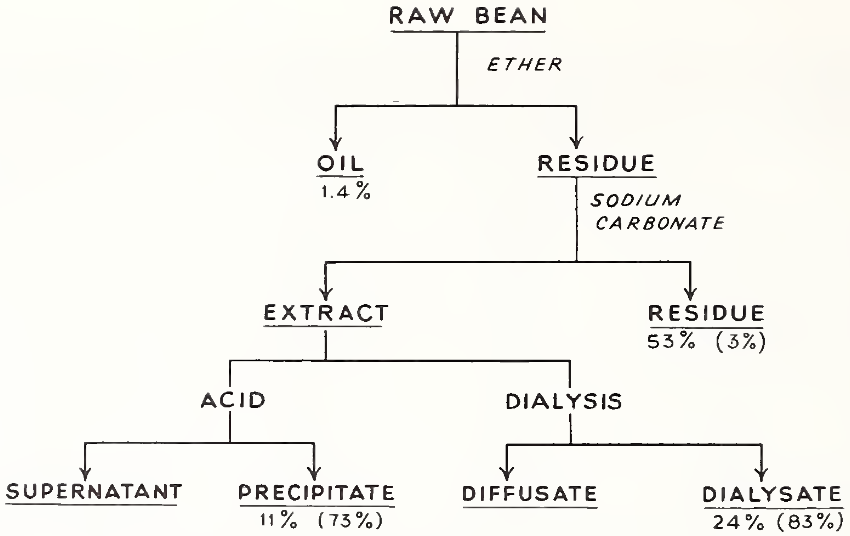

Figure 1. Scheme for production of high-protein nonflatulent concentrate by acid precipitation or dialysis.

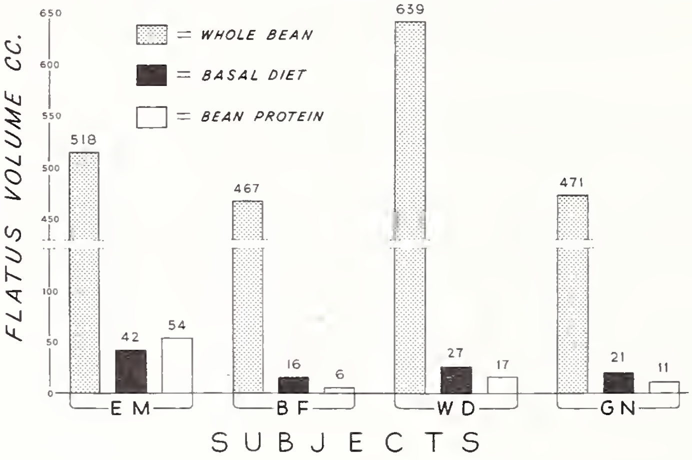

Figure 2. Flatus production of whole small white beans, compared with flatus produced by protein concentrate.

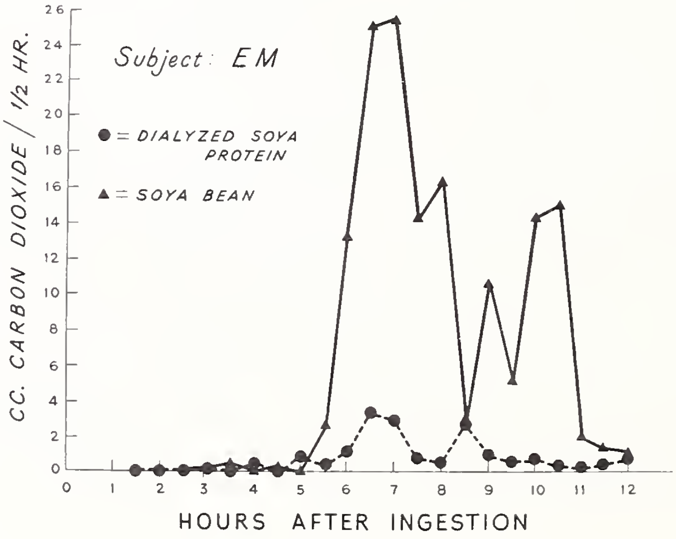

Figure 3. Flatus produced by soybean and soybean protein concentrate.

When either the acid precipitate or the dialyzate, which contain the major part of the protein from the bean, is eaten by our human test subjects (Figure 2), no increase in flatus occurs. In our flatulence assay technique, the human subjects eat the test meal and rectal gas is collected over a period of 8 to 12 hours depending upon the bean variety. The degree of flatulence of these bean concentrates was established by comparison of the total flatus collected from the same human subject after three test meals: whole beans, bean protein concentrate, and a normal nonflatulent meal for this subject. Figure 3 compares the typical flatus egestion pattern of one-half hour collection periods of carbon dioxide, a major gaseous component of flatus, from test meals of soybean and soybean protein concentrate. A significant reduction in flatulence has been brought about by application of this method of protein isolation from the whole bean.

This process may have commercial significance where it can be coupled with a major oil extraction facility to recover the protein for its high food value from press cake or defatted bean meal. Further, it could be applied to culls, screenings, market rejects or beans damaged by adverse weather or processing.

SYMPOSIUM ON ROOT ROT OF DRY BEANS

RESULTS OF FIELD EXPERIMENTS ON MICROBIOLOGICAL AND CULTURAL METHODS FOR CONTROL OF FUSARIUM ROOT ROT

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Among the many practices used to reduce Fusarium root rot in beans, various crop rotations have probably given the best and most dependable results. Extensive studies by microbiologists have indicated that crop rotations do not destroy the pathogen but stimulate a temporary microbiological suppression or semiabortive nutritional diversionary effect, which turns the "attention" of the pathogen to other things. The possible importance of the mere stimulation of plant growth so that the plant is able to escape or overcome the effects of the Fusarium has not been ruled out nor given much obvious attention.

In the Northwest, especially in the newly irrigated lands of the Columbia Basin, farmers have found it impractical to use effective crop rotations or to wait for the development of bean varieties resistant to root rot. Therefore we have given much effort to finding direct means of controlling the disease. Because chemicals have not done the job, we have considered the warnings of Rachel Carson and have given much effort to direct application of microbiological treatments and use of various cultural methods.

Microbiological methods. We were impressed with the possibilities in applying organic straws and meals, concentrated in or below or beside the seed furrow, so as to bring to bear on the "primary infection court" of Fusarium, individually or all together, the microbiological factors reportedly effective against this pathogen and others. We had hoped to duplicate with a small amount of organic matter, strategically placed, what is accomplished with many tons of organic matter plowed under as crop residues.

We reduced root rot in the treated area. Alfalfa, among many materials, gave the best and most lasting results. Table 1 shows the root-rot-reducing effects of autoclaved alfalfa in a commercial field and the results of root readings at 6 weeks after planting and at harvest. The fungi indicated were isolated from healthy bean roots and grown in culture for 30 days on the autoclaved organic materials. They were introduced as possible "competitors" to the pathogen. In this and in later tests autoclaved alfalfa alone gave as good results as added "competitors"--or even better. These treatments were applied at a rate of 50 lb. per acre in the seed furrow at planting time, in 4 replicated 2-row plots. Yield increases were not statistically significant.

Table 1.--Effects of organic matter treatments in the seed furrow on intensity of Fusarium root rot in young and in mature bean plants[a]

Treatments	Disease index[b]	
	6 weeks after planting	harvest time, 14 weeks
Alfalfa + *Fusarium solani*[c]	55	68
Alfalfa + *Sepadonium* sp.	32	60
Alfalfa + *Cephalosporium* sp.	6	55
Barley straw + *Fusarium solani*	3	37
Barley straw + *Sepadonium* sp.	19	61
Barley straw + *Cephalosporium* sp.	11	64
Alfalfa alone	52	41
Barley straw alone	41	62
Check, no treatment	35	81

[a] Finely ground material autoclaved and inoculated with a fungus "competitor" 30 days before use, or not inoculated, applied dry, directly in the seed furrow, 50 lb./acre, at planting time.

[b] Six-weeks data, average of 2 replications of 20 plants each; harvest-time data, average of 4 replications of 20 plants each. The higher the index the more severe the disease.

[c] Only slightly pathogenic.

Encouraged by the fact that small amounts of alfalfa applied directly with seeds would reduce root rot, even though yields were not increased, we decided that possibly larger amounts placed below the seed, so as not to interfere with germination, would accomplish both a reduction in root rot and increase in yields. Organic materials were placed in bands to match the 22-inch bean-row spacings at a rate of 1,000 lb./acre. A John Blue dry fertilizer applicator was used to apply the materials 4 inches deep in the soil. Half the plots were treated 3 weeks before planting and half at planting time. The organic matter applied at planting time slowed down plant emergence and reduced the plant stand. That applied prior to planting had no detrimental effects upon plant emergence and reduced root rot (Table 2). However, again, no significant benefit to yield was obtained. Many variations of these treatments were tested. Although the disease was frequently reduced, yield increases were seldom obtained. Further, the effects of such treatments were found to be very sensitive to environmental variations. For instance cool, rainy weather after alfalfa treatments would sometimes nullify their beneficial effects. This was especially noticeable in fields where high rates of nitrogen fertilizers had been applied.

Table 2.--Effects of time of application of organic materials below seed level on *Fusarium* root rot of beans

Treatments[a]	Root-rot index	
	Planting time	Preplanting[b]
Alfalfa pellets[c]	83	12
Autoclaved alfalfa meal	68	37
Check, none	80	52

[a] Applied at rate of 1,000 lb./acre in bands 4 inches deep, directly under seeds which were 2 inches deep.

[b] Three weeks in moist soil.

[c] Commercial livestock feed.

The failure of localized treatments to improve yields has been explained by recent experiments. Results show that the tap root and below-ground parts of the hypocotyl, where *Fusarium* rot is first obvious, are not necessarily the most important locations of pathogen damage. This has been shown by reciprocal transfer of soil between noninfested and *Fusarium*-infested fields, with beans being grown in "islands" of noninfested soil 4 to 6 inches in diameter by 4.5 to 8 inches deep, placed in *Fusarium*-infested fields and in similar islands of *Fusarium*-infested soil in noninfested fields. Plants grown in the infested field, regardless of their protective islands and absence of rot on the tap root and hypocotyl, are reduced in size and yield below plants in similar-sized islands of infested soils in noninfested fields. Obviously the fate of the lateral root system beyond the islands is at least as important as the fate of the tap root and hypocotyl in determining plant yields. This observation probably explains why localized *Fusarium* controls have failed to give yield increases.

Cultural practices. In conducting root rot control experiments in any badly infested field one can be impressed nearly always by the great variation in vigor of plant growth and yields from one part of the field to another. Usually, also, it is evident at the end of the experiment that some of the natural, uncontrolled factors operative in at least certain parts of that field were more effective than treatments in reducing the effects of the *Fusarium*. To study this field variation and to attempt to discover the factors favoring the "good spots" as opposed to the "bad spots," plants and soil samples were collected from both kinds in several fields. Seed yields were found to vary from 500 to 2,200 lb./acre in "bad spots" and from 1,700 to 4,500 lb./acre in "good spots." However, when the soil samples were assayed by inoculation of bean seedlings in the greenhouse, the *Fusarium* was found to be nearly uniform in distribution and activity throughout the fields. It was evident that variability in yield was due mainly to factors other than variation in inoculum potential of the pathogen. The most obvious difference between spots in the field was the difference in appearance of the irrigation ditches. The good spots had deep ditches, with the bean plants sitting high and dry, while the bad spots had wider ditches and showed evidence of subjection to more wet puddled soil conditions.

This observation suggested control by planting beans in high beds with deep ditches. Accordingly, last year we tried this treatment in two infested fields, one in which 100 lb. of actual nitrogen had been applied in ammonium nitrate and the other where no nitrogen was applied. Preplanting applications of alfalfa hay pellets and bean straw pellets were combined with the high bed experiment. The high beds were prepared with large 14-inch discs, then packed before application of the treatments and planting. The high beds were approximately 8 inches above the bottom of the ditches on either side as compared with a 3- or 4-inch height of regular bean rows. The ditch centers were 44 inches apart, to match the ditch spacing of two regular 22-inch rows. The beans planted in the high beds were in rows 14 inches apart. Root rot was decidedly reduced by the high bed planting and by the organic matter treatments in all plots. But, alas, the small yield increase was not statistically significant. In this test the nitrogen application was detrimental to yields. Another high bed study with 4 different varieties gave similar results. Observations in Fusarium-infested pea fields also indicate the desirability of the "high-dry" spots in the fields. There is certainly a principle here worthy of further study.

Another principle we have attempted to exploit in a cultural practice is the fact that widely spaced bean plants usually show less root rot than those growing closer together. When pinto and red Mexican varieties were planted at rates of 75 lb. and 35 lb. per acre in both noninfested and Fusarium-infested fields, wide-spaced plants in the infested field had a greater increase in yield per plant than did wide-spaced plants in the noninfested field. However, total yields were best in both fields with the higher rate of seeding.

Table 3.--Effects of plant and row spacings on seed yields of red Mexican beans in Fusarium-infested land[a/]

Plant spacing in the row	Row spacings		
	22-inch	14-inch	7-inch
inches	lb/acre	lb/acre	lb/acre
2	1989	2355	2416
4	2066	1853	2546
6	1650	1912	2305
8	1479	1837	2270

[a/] Average data from four replications of each treatment.

During the past season yields of both pinto and red Mexican beans were increased on infested land by reducing the row spacing from 22 to 14 and 7 inches (Table 3). Narrow rows gave greater coverage of the ground than is obtained with normal 22-inch spacing. This nearly complete ground cover not only permits increased yields but makes possible more effective use of the weedicide chemical EPTC (ethyl N,N-di-n-propylthiolcarbamate) which gives good weed control for 6 to 8 weeks after proper application. However, weed control after this time is dependent upon ground cover. Beans planted in 22-inch rows in Fusarium-infested land seldom provide sufficient cover to control the late-emerging weeds. When planted in 14- or 7-inch row spacings the ground cover is nearly complete. A new cutter utilizing the "rod weeder" principle on a 4-wheel tractor was satisfactory for cutting the plots planted in the narrow row spacings.

ECOLOGICAL ASSOCIATIONS AND PARASITISM IN A BEAN ROOT ROT SOIL

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The associations and interactions of soil micro-organisms in a bean-root-rot soil were investigated with the plate-profile technique for isolation purposes. The fungi were isolated on Difco corn-meal agar and identified as to genus. The plots were sampled during the growth of a bean crop in a five-year rotation. Compatibility of the micro-organisms was based on the frequency of isolations of two or more of the organisms on a petri plate.

More than 80 genera of fungi from over 3,000 isolations were identified but fewer than 20 genera occurred in sufficient frequency to establish an association. Often as many as five organisms were found growing together on a plate. The most frequently isolated fungi in descending order were Fusarium, Rhizoctonia, Mucor, Pythium, Sepedonium, Trichoderma, Penicillium, Alternaria, Gliocladium, Rhizopus, and Streptomyces. Of this group, Fusarium was isolated and identified 2,890, Rhizoctonia 1,080, and Pythium 770 times. Thielaviopsis, which is also a root-infecting pathogen ot beans, was isolated infrequently. The high frequency of isolation of the bean pathogens would indicate that they were quite active in the soil during the growth of the bean plant.

The frequency of isolation of more than one organism would indicate a close association of these organisms in the soil. The bean pathogens as well as Mucor and Sepedonium and the many nonsporulating fungi which could not be identified probably can be classed as highly active soil fungi that are compatible with most other organisms. On the other hand, the infrequent isolation and association of some of the other micro-organisms would indicate either incompatibility or inactivity. The infrequent isolation and association of Streptomyces may be the result of the slow growth of this organism, although there are indications that it might be quite incompatible with the other organisms. Other negative associations include Penicillium and Gliocladium, Streptomyces, or Sepedonium; Rhizopus and Alternaria; Streptomyces and Sepedonium; and Alternaria and Trichoderma. Bacteria were found growing in close association with most of the fungi. This association was both parasitic and symbiotic. Bacterial necrosis of Fusarium and Rhizoctonia has been discussed at previous meetings.

The parasitism of Fusarium by an Actinomycete has also been observed. It has not been possible to culture the Actinomycete in the absence of Fusarium. Laboratory media ordinarily recommended for the isolation of Actinomycetes were unsatisfactory. The growth of the Fusarium was generally stopped five days after inoculation with the Actinomycete. Other types of parasitism observed included that of an unknown fungus which coiled around and frequently penetrated the mycelium of Rhizoctonia and the trapping of nematodes by Arthrobotrys and Dactylaria. Very few instances of antibiosis were observed and very few observations were made of direct lysis of fungus mycelium in culture.

SURVIVAL AND INOCULUM POTENTIAL OF FUSARIUM

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Fusarium oxysporum f. melonis causes wilt in muskmelon and is known to survive in field soil in the absence of the host for at least 10 years. Pure cultures have been maintained in the laboratory in dry soil held at 3°C. for up to 20 years. The survival unit is the chlamydospore. Population levels in naturally infested sandy loam field soil have been determined by isolating the fungus by a soil-suspension method and testing the F. oxysporum isolates in a pathogenicity test. In soils cropped annually to muskmelon population levels ranging from 80 to 200 propagules have been obtained. Fertile soils supporting populations of approximately 20 propagules per gram were shown to cause a wilt incidence of such magnitude to render the growing of a susceptible crop unprofitable.

In naturally and artificially infested soils the highest incidences of wilt were found in soil fertilized at high rates; the rate of the wilt was closely correlated with the amount of nitrogen in the fertilizer. Since nitrogen was found to have no effect on size of population of the fungus, the effect of nitrogen was presumed to be on the muskmelon plant. The nitrogen increased its susceptibility. Magnesium, calcium, phosphorus and potassium had little effect on wilt. Amendments of naturally infested soil with peptone, sucrose, and 95% ethyl alcohol at 1500 to 2000 pounds per acre increased the incidence of wilt. Soil amendments with peptone, sucrose, and alcohol were found to increase the population of the fungus in the soil.

FREQUENCY OF LESIONS ON BEANS INCITED BY SOIL-BORNE PATHOGENS IN THE SALINAS VALLEY, CALIFORNIA

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At least 14 species of fungi cause lesions on the underground hypocotyl or roots of beans. Often several are primary invaders of a single plant and thus root rot is often referred to as a disease complex. However, the lesions are formed individually and the effect on the plant when more than one pathogen is involved is probably additive rather than synergistic. The following are some of the more important pathogens on beans in the Salinas Valley in California.

Rhizoctonia solani, one of the most damaging pathogens, forms relatively few lesions on the plant, but they are large and deep. The work of Christou in our department showed that the fungus hyphae grow and branch profusely on the surface of the bean plant prior to penetration. Thus the attack is by means of a mass of hyphae covering a relatively large surface area.

Fusarium solani f. phaseoli, on the other hand, forms numerous, small linear lesions, which eventually coalesce. Each is usually formed by a single soil-borne chlamydospore which germinates and forms a small thallus before entering the plant. Each lesion may represent a different clone of the fungus.

This pathogen is most prevalent on the hypocotyl, but it often vigorously attacks the tap root.

Thielaviopsis basicola also forms many small scattered lesions which originate from separate propagules of the fungus and upon coalescing result in a blackened damaged area. Unlike Fusarium solani, rootlets are the most common entry for this fungus. The lesions are brown and linear in the early stages but turn black as the fungus forms numerous chlamydospores.

The many individual lesions formed by both F. solani f. phaseoli and T. basicola reflect the heavy populations of these fungi in bean field soils.

Pythium and Phytophthora species are only occasionally important in California, but can be destructive to the root system. They can also cause damping-off. They often invade the tips of the small rootlets.

Sclerotium bataticola and Sclerotium rolfsii are destructive only in hot weather. They may attack at ground level by a mass of hyphae or form single, linear lesions at the base of the hypocotyl.

Dendryphion sp. attacks the underground parts of the bean, causing small dark lesions resembling those of Thielaviopsis. This fungus is more prevalent late in the growing season.

A study was made of the primary causative agents of the individual lesions appearing on 3-week-old small whites in fields in the Salinas Valley. Beans are a summer crop grown under irrigation in this area. Some of the plants analyzed were planted in May and some in June. Air temperatures in May averaged 60°F. and June 68°F. in the area. F. solani f. phaseoli was found to incite proportionally more individual lesions on small whites from these fields than any other pathogen. Rhizoctonia was isolated more commonly from the transition zone than from the upper part of the hypocotyl or roots. Thielaviopsis was most commonly isolated from the roots and was found more frequently in the May than in June plantings. The June plantings contained a relatively higher proportion of Dendryphion lesions on the roots. Warm climate pathogens such as Sclerotium bataticola have not been recovered from lesions on beans in this area. Sclerotinia sclerotiorum which occasionally occurs on older plants in the Salinas Valley was not found in these isolations.

OBSERVATIONS ON THE POPULATION DYNAMICS AND SURVIVAL MECHANISMS OF THIELAVIOPSIS BASICOLA IN SOIL

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Evidence was obtained through use of the most probable number (MPN) assay, employing carrot disks as a substrate, that growth of Thielaviopsis basicola in soil is associated almost exclusively with its pathogenic activities. Both steamed and raw field soils as well as host (bean) and nonhost (wheat and corn) plants were used. After addition of the pathogen to soil (about 2500 propagules/gram) a decrease in population was observed in all treatments over a two-week period, after which a rather constant low level (between 100 and 500 propagules/gram) of inoculum persisted during the course of a 15-week sampling period. Pathogen numbers increased only in the rhizosphere of the host plant and this increase was associated with symptom expression on the roots. This increase in propagules was attributed to sporulation at lesion surfaces and limited mycelial growth and often abundant sporulation in the immediate rhizosphere. No significant differences were observed in behavior of Thielaviopsis populations in steamed and raw field soils.

The Rossi-Cholondy slide technique was modified and employed to follow propagative and survival structures of T. basicola over the course of root-rot development. Slides were buried at a 45° angle in soil and bean seeds were planted in such a manner that the developing root system would grow down over the upper surface of the slides. Periodically, over the course of disease development, slides were uncovered, patterns of root systems in contact with the upper surface were traced on the opposite surface of the slide, removed from the soil, stained with phenolic Rose Bengal, and examined microscopically. Reproduction and growth were observed only for the pathogen in the rhizosphere. During the early phases of disease development mycelium and phialids producing endoconidia were observed, particularly in the vicinity of lesions; this was followed by the simultaneous production of endoconidia and chlamydospores and rapid lysis of mycelium. The latter phenomenon was associated with extremely dense bacterial populations surrounding the hyphae. In addition to these well-known reproductive structures of this pathogen several other potentially important structures were associated with Thielaviopsis that could be important as reproductive and survival mechanisms in soil. These included an apparent transformation of endoconidia into a smaller spherical mass which may represent a resistant spore form, production of arthospores by fragmentation of hyphae, and production of a globoid structure with a diameter 5 to 9 times greater than the width of the supporting mycelium. The latter structure was found only infrequently in the rhizosphere of well-decayed roots in raw field soil.

PATHOLOGIC HISTOLOGY AND APPARENT PHYTOALEXIN PRODUCTION IN BEANS RESISTANT AND SUSCEPTIBLE TO FUSARIUM AND THIELAVIOPSIS

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There are two main objectives in this investigation. The first is a comparative histological study of the pathogen-suscept relationship in bean varieties which are either susceptible or resistant to Fusarium solani f. sp. phaseoli and Thielaviopsis basicola. The second is to explore the possibility of developing a test by which a resistant plant would be identified, since a simple and precise test for resistance could greatly reduce the overall period of the breeding programme. P. coccineus L (Scarlet Runner), H 2051 (P. coccineus x P. vulgaris), and two varieties of P. vulgaris, (PI 203958), a USDA introduction, and red kidney were used. Red kidney is susceptible to both pathogens; the other varieties show various grades of resistance.

There was a remarkable similarity in the modes of ingress and pattern of early development of each pathogen in all varieties and the observations on development agreed with that described by Christou. F. solani penetrated mainly through the stomata and produced a vigorous mycelial mat in the substomatal cavity. From this mycelial mat groups of hyphae progressed intercellularly within the tissues. Although the early phases of development were similar in all varieties, hyphal development in the susceptible variety continued to be very profuse and the spread of hyphae within the tissues also was more rapid than in the resistant varieties.

T. basicola mostly penetrated the epidermal cells directly and developed characteristic finger-like "constricted hyphae" intracellularly. These produced "distributive hyphae" and "reproductive hyphae." The latter gave rise to intercellular and intracellular chlamydospores and to both chlamydospores and endoconidia on the surface of the necrotic tissues. Reproductive structures were less numerous in varieties with higher levels of resistance.

With infections by either pathogen, brown substances accumulated in cells beyond the point of hyphal invasion, especially in resistant varieties, although the rate of hyphal development within tissues exceeded the spread of necrosis in early phases of the disease. This reaction was more marked with infection by T. basicola. In Scarlet Runner, hyphae of T. basicola often were restricted to the outer cortical cells. Infection of Scarlet Runner by either pathogen at points close to or above soil level sometimes resulted in hypertrophy of the cortical cells internal to the lesion, with the ultimate formation of a wound periderm around the lesion. A protective barrier also developed in H 2051 and PI 203958, but in these varieties cell division generally began in the endodermoid layer.

Histological observations indicated clearly that wound periderm is only secondary as a barrier to the pathogens. The main reasons are: (1) the wound periderm was not always associated with lesions but hyphal development in resistant varieties was restricted in spite of its absence; (2) in the resistant varieties, hyphae of T. basicola were not observed in cells immediately outside the periderm, although very sparse intercellular strands of F. solani sometimes were observed; (3) in varieties showing intermediate resistance the wound periderm developed mainly in the endodermoid layer, and even in the susceptible red kidney an endodermoid wound periderm sometimes was formed partially when T. basicola was the infecting organism.

On the other hand, resistance of bean to F. solani and T. basicola apparently is associated with phytoalexin production. Partially mature green pods inoculated with a spore suspension either of Cladosporium cladosporioides or F. solani f. sp. phaseoli produced diffusates which were inhibitory to the inducing fungi and to T. basicola. Diffusates from varieties known to be resistant to F. solani and T. basicola caused greater inhibition than those from the susceptible variety. Diffusates induced by C. cladosporioides caused greater inhibition than that induced by F. solani. C. cladosporioides, which is nonpathogenic to beans, induced a greater concentration of the inhibitory factor to which it also was more sensitive than either F. solani or T. basicola. Spectrophotometric examination revealed basically similar absorption curves in diffusates from all varieties. Similar absorption curves also were obtained when extracts of Fusarium-infected hypocotyls were spectrophotometrically examined. In bioassays of extracts from hypocotyls, that from infected Scarlet Runner showed marked inhibitory properties, whereas that from infected red kidney was only very slightly inhibitory when compared with extracts from the healthy plants.

GERMINATION OF CHLAMYDOSPORES OF THIELAVIOPSIS BASICOLA

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The fungus Thielaviopsis basicola (Berk & Br.) Ferraris is a soil-borne fungus which attacks the roots of beans and many other plants. The chlamydospores are produced in great abundance all through cortical tissues and on the root surface of the host. The chlamydospores are made up of 2-3 thin-walled hyaline basal cells surmounted by 1-8 brown or black segments. These segments separate into individual cells, each of which may germinate. The breakup of the chlamydospores into individual cells appears to be necessary before germination can take place. Germination occurred readily only after the chlamydospores had been "aged" on the surface of moist, nonsterile soil. Natural substrates such as raw carrot slices, freeze-dried roots, extracts of decomposing plant residues, etc. stimulated germination, which did not occur when soil extracts or water alone were used.

During germination, the germ tube always emerged at one end of the cylinder-like chlamydospore cell at the juncture of the walls, and a lid or operculum was clearly visible at that point. It was further shown that the cytoplasm inside the chlamydospore cell is not attached to the wall and that it is possible to separate the two. It is then evident that each chlamydospore cell can be compared to a miniature Van Tieghem cell, each end capped by an operculum. A septal pore is present in the center of each operculum. At no time was germination observed taking place through this pore. Eighteen to 24 hours after germination the mycelium either continues to grow or an endoconidiophore is formed which gives rise to endoconidia.

PHYSIOLOGICAL ASPECTS OF PATHOGENESIS BY RHIZOCTONIA SOLANI

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Rhizoctonia solani (isolate RB) produced pectinolytic and cellulolytic enzymes inductively in culture. Both types of enzymes were readily obtained from bean hypocotyl tissue infected by this pathogen. The polygalacturonase (PG) from Rhizoctonia-infected tissue differed from that produced in culture with respect to hydrolytic products, viscosity reduction-reducing group ratio, and thermal stability at various pH levels. Pectin methylesterase (PME) was produced by the pathogen as well as the host plant. The fungal PME was not activated by cations or influenced by dialysis, whereas the plant PME was activated by cations and activity was reduced by dialysis. Diseased tissues were considered to contain a mixture of these two types of PME.

Studies on the enzymatic maceration of plant tissue indicated that PG was the principal enzyme involved and that cellulase and PME were of secondary significance in this process. The PG associated with diseased tissue was most reactive under acid (pH 4.5-5.0) conditions and more readily hydrolyzed pectic acid than pectin. This enzyme did not attack calcium pectate. It was shown through the use of Ca^{45} that calcium was mobilized and accumulated in and immediately around developing Rhizoctonia lesions. From studies with other diseases it may be assumed that other solutes and ions also accumulate in the infected area. This phenomenon would be expected to liberate and activate the host PME in and around the developing lesion, since this enzyme apparently is involved in a cation exchange and is liberated from host cell wall material by cations. The action of this enzyme in the presence of the fungus and its PG would be expected to act synergistically with respect to pectin degradation; action of host PME in advance of the pathogen and its PG is believed to lead to demethylation of the pectin and subsequent formation of calcium pectate that is resistant to PG action. This latter series of events may be regarded as an induced mechanism of tissue resistance to pathogen spread within the host. This hypothesis is supported by the following observations: accumulation of calcium in the infected tissue, greater concentrations of free host PME in diseased than in healthy tissue, and a greater resistance of tissues around lesions to enzymatic maceration than comparable healthy tissues.

Plants between 4 and 12 days old were extremely susceptible to Rhizoctonia, those between 12 and 21 days old were somewhat more resistant, and those greater than 3 weeks old were considered resistant. Analytical studies of the pectic substances and calcium content of bean hypocotyls of different ages revealed the following relationships. Susceptibility was inversely related to the calcium content of the tissue as well as to the carboxyl group content of the pectic substances. Also, the susceptibility of hypocotyl tissue to enzymatic maceration decreased with plant age. Thus, the role of calcium pectate in resistance of tissue to Rhizoctonia was implicated with studies concerning lesion development as well as with studies on the natural development of resistance of the host with age.

Rhizoctonia produced cellulase with activities comparable to that which has been described for C_1, Cx, and cellobiase. These types of activities were demonstrated in vivo and in vitro. This organism may be considered cellulolytic since it was capable of utilizing native cellulose as a sole carbon source for growth in a mineral basal medium. Studies with diseased tissues revealed a loss in birefringent properties of host cell walls in the older portions of developing lesions. This may be attributed to a destruction of the crystalline properties of the cellulose in the cell wall. This activity was associated with the collapse of cells in diseased tissues and was considered to contribute to the formation of the characteristic concaved appearance of mature Rhizoctonia lesions. Cellulase apparently was more important during the latter phases of pathogenesis and thus more closely associated with the saprophytic activities of this pathogen, whereas PG was considered to be of great significance in terms of intercellular movement within the host associated with disease initiation.

CROPPING SEQUENCE AND ENVIRONMENT AS RELATED TO BEAN ROOT ROT

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Many factors influence the development of bean root rot. These have been the subject of investigations by individuals here at this symposium. Your investigations have shown how the pathogen survives in the soil and the importance of nutrition, plant exudates, and crop residues on the germination and infection processes. You have observed the differences between bean varieties in their ability to resist infection. This information has been the basis for inheritance studies as well as extended plant-disease-resistance breeding programs. Others have observed that soil temperature and moisture influence disease development. Finally, there are those whose attention has been directed to investigations on specific interactions among the soil micro-organisms as they relate to activity of the root rot pathogen. These activities include competition, antagonisms, fungistasis, lyses, and parasitism.

Opportunities for obtaining a good field test for root rot in beans in Michigan are few and far between. Since our investigations on the influence of cropping sequence on bean root rot began in 1960, we have had only one year in which root rot was sufficiently severe on the Ferden farm to cause a significant reduction in yield. Other environmental factors were instrumental in affecting yield in other years, but when results from the Ferden farm were correlated with observations on disease outbreaks throughout the State, the information obtained over the years appeared significant. For example, root rot was ordinarily less severe in beans planted after corn. Other crops preceding beans in the rotation in which root rot appeared to be less severe were sugar beets, wheat, and sweet clover. The disease was severe after barley and the most severe after a continuous cropping of beans in which rye was fall planted and then plowed under as a green manure crop prior to planting time.

To verify the results for investigations, a questionnaire was prepared and mailed to growers in two Michigan counties. The returns supported our observations that root rot was most severe in beans planted after beans and least severe when planted after corn. Several growers in Tuscola county indicated that root rot appeared less severe in beans planted after wheat. This too was in agreement with our observations. When asked whether soil compaction, cold weather or wet seasons affected root rot as compared to loose soil, warm weather and dry seasons, the growers were nearly all in agreement that the cold, wet weather and compacted soils favored the development of root rot. We too had made this observation. The results from these observations as well as the Ferden farm experiments have been a basis for future investigations on the role of environmental factors in the development and control of root rot in beans.

PROGRESS REPORT ON BREEDING FOR RESISTANCE IN BEANS TO ROOT ROT CAUSED BY FUSARIUM SOLANI F. PHASEOLI

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This work has been in progress for a number of years. Our early results could be explained by assuming that resistance is conditioned by the presence of two independent genes, one dominant and one recessive. This hypothesis explains (1) that F_1 plants are susceptible and (2) that the ratios in the F_2 are 13 susceptible to 3 resistant.

This report is based on studies of crosses of resistant F_4 lines from earlier crosses. These F_4 lines were used as parents: (1) for another round of backcrosses to the original commercial variety used in the particular cross and (2) for crosses with other susceptible commercial varieties. The F_1 plants of these crosses were planted in the field and harvested. In the F_2 nursery, each row was from a single F_1 plant. Twenty plants were harvested from each of the F_2 rows. Since there were far more plants than there is room to test them, some discretion for seed coat color was made in selecting which plants would be tested in the greenhouse.

Greenhouse tests. A greenhouse bed equipped with a thermostatically controlled heating coil to keep the soil at 80°F. was used because the heat produces better infection of the plants. The bed is marked off to give 150 15-inch rows about 4 inches apart. Plastic pot labels have been prepared with numbers (1 through 150) burned into the labels to distinguish the rows. Four rows each of the susceptible and resistant stocks are planted at random, with 10 seeds per row. Seventy-one hybrid plants are tested, each with two replications of 10 seeds. The seeds are planted in a groove made in the soil about one-inch deep. Before the seeds are covered, they are watered with 10 cc. of spore suspension of Fusarium calibrated to give about 100,000 spores. When the cotyledons appear they are again washed with a spore suspension.

The readings are made 23-28 days after planting. Each plant from each row is scored on a scale of 0-4 (0 - no symptoms, 1 - slight discoloration, 2 - marked discoloration, 3 - deep penetration of the disease, and 4 - plants dead). The average score for the row is taken and the average of the two replications is compared with the average of the four replications of the controls. The plant progenies with scores as low as the resistant check are considered to be resistant, unless there is a great variation between replications. The beds are steam sterilized between plantings and are fertilized with ammonium sulphate before replanting.

The method is somewhat subjective, because each plant is graded by sight. We feel that the progeny test of a plant that passes this test has resistance. But this judgment is often wrong, as is shown by the number of F_4 progenies from supposedly F_3 resistant plants that turn out to be susceptible. F_4 rows are planted in the field from the reserve seed of the resistant F_3 plants. At maturity, 20 plants are harvested from each row, which are later tested in the greenhouse. This gives an opportunity to compare the reaction of a number of related plants before judgment is made. Seven breeding projects are under study:

1. (Sutter Pink X P.1. 203,958) F_4 X Sutter Pink (BC_1). One-hundred F_3 plants were tested and 20 were rated as resistant. Progeny from these 20 F_3 plants gave 16 susceptible and only four were segregated for resistance with a total of (9 resistant:47 susceptible).

2. (California Red X P.1. 203,958) F_4 X California Red (BC_1). Twelve plants of 43 tested in F_3 were classed as resistant but nine of these proved to be susceptible in F_4. Four segregated (10 resistant:33 susceptible).

3. (California Red X P.1. 165,435) F_4 X California Red (BC_1). Twenty F_3 plants were rated--10 susceptible, 10 resistant. Progeny from the 10 resistant gave seven susceptible and three segregated in the ratio of (5 resistant:23 susceptible).

4. (California Red X P.1. 203,958) F_4 X Standard Pink. In the F_3, 11 resistant and 17 susceptible plants were obtained. The F_4 from the 11 resistant F_3 plants were all susceptible. This was certainly not expected.

5. (California Red X P.1. 165,435) F_4 X Standard Pink. Twelve plants were tested in F_3 (5 resistant:7 susceptible). Progeny from all five resultant plants segregated in F_4 (18 resistant:54 susceptible).

6. (California Red X P.1. 203,958) F_4 X Small White. Seventy-one F_3 plants gave 20 resistant:51 susceptible, but the F_4 revealed 11 of the 20 were susceptible. The segregation of the other nine was 15 resistant and 117 susceptible. The randomness of the population may have been disturbed because only white seeded plants were tested in F_4.

7. (California Red X P.1. 165,435) F_4 X Red Kidney. In the F_3, 21 plants were tested giving a ratio of 16 resistant to 55 susceptible. Progeny tests of the resultant plants showed nine were susceptible. Six segregated 18 resistant:61 susceptible and one was not tested. A similar cross (C.R. X P.1. 203,958) F_4 X pinto has been tested in F_3. Six plants segregated, 9 resistant: 30 susceptible. Eight of the nine resistant plants were tested in F_4. Five were resultant and 3 segregated, 8 resistant:25 susceptible.

On the 2-gene model where resistance is conditioned by aaBB or aaBb we expect 3/16 in the F_2 to be resistant. In a random sample of F_3 we would expect 9 aaBB to 6 aaBb, so that 15/64 should be resistant and 9 of these should be homozygous. The data obtained from the seven sets reported show that no true-breeding resistant F_4 lines have been obtained. These facts are not explained by the present working hypothesis. From a practical breeding point of view, however, if we can reclaim some resistance after these repeated backcrossings, the possibility of transferring resistance seems probable if large enough populations are tested.

Reserve seed from the resistant F_4 plants shown of the first 3 breeding programs were planted in the breeding nursery and backcrossed to the recurrent parents. Hybrids were obtained on 65 plants. The self-pollinated seed from these will be tested and only hybrids which were made on resistant plants will be continued.

Experiments in cultural methods have been tried. (1) Seven seeds were planted in a 7-inch pot and the top inch was covered with sand held in place with a plastic collar. The seeds were planted in the soil so that the hypocotyl emerged in the sand layer. The disease symptoms could be seen by removing the collar. This system did not work. Infection was poor. The soil temperature was too low. In the beds the soil temperature is kept high by electric coils. (2) The seeds were planted individually in collapsible cups open at both ends.

It was hoped that by using this method it would be possible to save the resistant plants and transfer them to pots to grow to maturity. The tar paper cups disintegrated so badly that they could not be used to transplant and there was a toxic substance in the tar paper that prevented the growth of the fungus so that the readings of root symptoms were not dependable.

PROGRESS IN BREEDING FOR ROOT ROT RESISTANCE IN MICHIGAN NAVY BEANS

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The source of genetic resistance to Fusarium root rot which we have used is N203, a tropical black bean. The original cross to Michelite was made by D. H. Wallace of Cornell University and generously supplied to us in the form of segregating populations at the F_2 and F_3 level.

In our material we have found resistance to behave as a polygenic trait with susceptibility showing phenotypic dominance. Consequently we have abandoned recurrent backcrossing in favor of alternate backcrossing and intercrossing. A complete cycle now involves backcrossing, selfing, screening, intercrossing partially resistant plants, selfing, screening, and then backcrossing again to initiate the next cycle.

Currently we are initiating the second cycle of the alternate program. Each cycle requires two years to complete. We anticipate at least one more cycle in addition to the one being initiated at present. Following the last cycle there must come at least three generations of selfing and testing with selection before we can expect to produce a line suitable for farmer use.

BREEDING BEANS RESISTANT TO ROOT ROT--FIELD TESTS IN NATURALLY INFESTED SOIL

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The extent of Fusarium root rot of beans in the field depends on a complex of interacting microbiological and ecological factors affecting both the plant and various pathogens. Therefore, screening beans for resistance to selected isolates of Fusarium solani f. phaseoli under selected conditions may not be practical. We have chosen to make most selections for resistance to root rot in naturally infested fields. This permits simultaneous screening for resistance to other diseases, and for plant type and adaptability.

Testing is begun by tagging F_2 single-plant selections for early maturity, type, and freedom from virus symptoms. At harvest, having matured in naturally Fusarium-infested soil, plants are further selected for strong root characteristics, not necessarily complete freedom from root rot. In some instances, the F_3's have been tested in the greenhouse by various means of direct inoculation with pure cultures of Fusarium solani f. phaseoli. However, since the results of such tests have not always agreed with our field observations, we have chosen not to put a great deal of stock in greenhouse tests. For instance, Black

Turtle Soup bean, which produces well under severe root rot conditions in the field, does not look good when inoculated directly with pure cultures of *Fusarium*. Furthermore, some hybrid lines, while susceptible to early infection by *Fusarium*, appear to have a greater capacity than others to recover and, in the long run, show little real damage from root rot.

Because of the variability frequently encountered in field tests, a particular line may look much better in one location than in another. We therefore use a testing method which not only tends to increase the uniformity of infection throughout the field, but also gives us a direct comparison of the bean lines under test with a known susceptible check variety, regardless of location in the field. This method consists simply of mixing seeds of the line under test with a larger number of the seeds of the known susceptible variety. Of course the seed of the susceptible variety must be easily distinguishable from seed of the test line. For this reason we plant susceptible Columbia pinto seeds with red, black, pink, or brown-seeded test lines. With pinto or other variegated seeds being tested, we plant susceptible red Mexican seeds.

To increase the activity of the pathogen and the susceptibility of the beans, the seeds are planted thickly, about 125 lbs. per acre in 22-inch rows. We have found that thick planting increases root rot and it also places a special stress on the beans to be tested. In this way, they are not only tested for reaction to root rot, but for their ability to compete with other plants. At harvest time, plants which have remained virus free are selected for early maturity, plant type, and yielding ability. Those with strong roots are bulked or retained as single-plant selections. In the most promising lines, seed weights per plant are compared with yields per plant of the known susceptible check plants in the same row. An example of such a yield comparison is shown in Table 1. This yield comparison may be just as important as the root appearance, if not more so. In some instances "strong-rooted" lines fail to yield as much as lines appearing to have only moderately strong roots.

Table 1.--Average seed yields per plant of test lines and of susceptible check varieties grown mixed in the same rows

Test line	Yield (grams)	Checks	Yield (grams)	Ratio test line/check
R-28 (pinto)	9.23	(red Mex. No. 12)	4.09	2.26
R-29 "	12.68	" " " "	3.90	3.25
R-30 "	12.09	" " " "	2.97	4.07
R-56 (red Mex.)	7.00	(Columbia pinto)	3.38	2.07
R-108 " "	18.48	" "	3.97	4.65
R-171 " "	22.50	" "	5.09	4.42
Bl. Turtle Soup[a]	4.05	" "	2.36	1.72
Red Mex. No. 1[b]	8.12	" "	4.16	1.95

[a,b] Commercial types susceptible to *Fusarium* infection, but generally more tolerant of the disease than the check varieties.

This type of yield measurement would appear to have excellent possibilities as a means of making selections for yielding ability, even in early generations. The yield of single-plant selections or the average yield of bulked selections can be compared directly with the individual plant yields of any variety with which they are interplanted. The interplanting (or mixed planting) takes care of the problem of field variability. However, it is evident that the difference in rate of maturity between the test lines and the checks account for part of the differences in yield per plant. This is indicated by the fact that red Mexican No. 1, which is susceptible to root rot and later in maturity than Columbia pinto, yielded consistently nearly twice as much per plant as Columbia pinto, when they were planted mixed together.

Some of our most promising lines are progeny of dry bean and snap bean crosses with PI 203958 with a backcross to the latter parent and further backcrosses and outcrosses to early maturing commercial types. We also have some promising lines from crosses made in Beltsville with some of the Coccineus X Vulgaris hybrids from New York. Yield data shown in Table 2 verify the effectiveness of our selection method. You will note that 3 of the resistant dry bean selections yielded comparably with commercial types on soil with a slight infestation of the Fusarium and much better than the commercial lines on soil heavily infested by the Fusarium.

Table 2.--Yields of commercial dry beans and hybrid selections in fields slightly and heavily infested with Fusarium[a]

Variety or line	Field No. 1--slight Fusarium	Field No. 2--severe Fusarium	Yield difference
Pinto U.I. No. 111	3255	2034	1221
Red Mex. U.I. No. 35	3189	2201	988
Black Turtle Soup	2791	2362	429
R-402 (pinto)[b]	3296	2957	339
R-17 (red Mex.)	3552	2975	577
R-12 (red Mex.)	3552	2999	553

[a] Average yields from 4 replications of 2-row plots, 20 ft. long, in each field.

[b] F_4 "R" lines selected for resistance to root rot, maturity was about the same as that of red Mexican U.I. No. 35 (110 days).

To compare our method with those used by other workers, certain lines which have been selected as "resistant" or "nonresistant" in our field tests were tested in Oregon, Idaho, and Michigan last summer. The results from these tests have not all been received or analyzed. However, certain of our lines observed in field plots at Twin Falls, Idaho, showed about the same relative resistance there as in our Washington tests. In an interchange of materials with Oregon breeders, who use cultured inoculum in their field tests, the reciprocal results were only partially in agreement.

INHERITANCE OF FUSARIUM ROOT ROT RESISTANCE OBTAINED FROM PHASEOLUS COCCINEUS

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Reports by McCrostie, Azzam, and Smith and Houston have all indicated at least one recessive gene is involved in the control of Fusarium root rot resistance. Smith and Houston reported that a homozygous recessive gene combined with the dominant allele of a second locus is required for the expression of resistance. The others have concluded that two or three recessive genes conditioned resistance.

In crosses with bean lines, deriving their resistance from Scarlet Runner, we have found a strong indication that the resistance is conditioned by dominant genes. We have not tried to determine how many genes are required, but the fact that we can get true breeding lines with various degrees of resistance indicates at least several loci are involved. The F_1's of crosses between the resistant lines and susceptible varieties exhibit a level of resistance very nearly as high as that of the resistant parent. This implies near complete but incomplete dominance. Both F_2 and previously untested F_3 populations have also given a high proportion of segregants with resistance nearly as good as that of the resistant parent. Plants with the reaction of the susceptible parent are relatively rare in these populations.

The different pattern of inheritance is undoubtedly related to the different source of resistance. Our experience indicated that the Scarlet Runner resistance is slightly better than that of N203. Our breeding lines also appear to have resistance slightly superior to that of N203. We have not been able to obtain segregants with resistance superior to that of Scarlet Runner from crosses between N203 and the lines deriving resistance from Scarlet Runner.

BEAN ROOT ROT BREEDING AT THE NEW YORK STATE AGRICULTURAL EXPERIMENT STATION, GENEVA

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The bean root rot breeding program at the Geneva Station is directed towards the development of Fusarium-root-rot-resistant snap beans. In this program, two generations are produced each year, one in the greenhouse and one in the field. The breeding material is evaluated in the field. Selections of resistant plants with desirable snap bean characteristics have been made from F_4, F_5, and F_6 generations originating from the first backcross progeny of white-seeded Tendercrop X Cornell root-rot-resistant lines. Root-rot-resistant selections of F_2 and F_3 generations of second backcross material have also been made. The second backcross material resembles Tendercrop in horticultural characteristics but has less resistance than the first backcross lines.

In a search for new sources of resistance during the past 5 years, 11 Plant Introduction accessions possessing resistance comparable to that of N203 have been found. Their inheritance of resistance is now under study. Resistance that is simply inherited would expedite breeding. Studies are in progress on methods for testing in the greenhouse. Lack of dependable methods has created confusion as to mode of inheritance of root-rot resistance. Under certain conditions, resistant plants may become severely infected. Under other conditions, susceptible plants may remain free from root rot. A reliable test must cause infection of all susceptible plants but must not infect tolerant plants.

REPORTS FROM LATIN AMERICA

VISITS TO DRY BEAN GROWING AREAS IN BRAZIL AND EL SALVADOR

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It was my good fortune to visit Brazil and El Salvador the early part of this year and to make a second visit to the latter country within the past few weeks to observe and study dry bean production problems. These trips were sponsored by the AID Technical Assistance Agreement of the Department of State.

The Brazilian trip was made primarily to help conduct with Dr. Francis Smith of the University of California a conference and seminar under the joint auspices of the Rural University of the State of Minas Gerais, Vicosa, Brazil, and the Purdue University AID Mission. About 32 participants from 7 states in Brazil attended. Most of those in attendance were devoting either full or part time to bean production research.

At the conclusion we visited dry bean growing areas of southern Brazil, including the states of Minas Gerais, Sao Paulo, and Guanabara, in which the city of Rio is located. About 10 years ago, I also inspected beans in the states of Santa Catharina and Rio Grandes. In Brazil as in other Latin American countries only dry beans are grown. If snap or string beans are desired, the pods of dry varieties are eaten. I'm sure the American housewife would be displeased if she had to string these beans as our mothers and grandmothers did years ago. It's amusing and sometimes irritating when we realize the demands made by the American snap and dry bean canners on the plant breeder. In the case of snap beans at present nothing but virus-resistant, white-seeded, round-podded and absolutely fiberless beans will be accepted. I'll go along with some of these characters but I can't see only white-seeded types. I'm happy that the dry bean processors are not quite as particular but the time may come when they will be. Thank goodness the quick freezers are not so demanding, since they accept colored-seeded varieties, some of which are equally as good as certain of the white-seeded varieties, if not better. How the Latin folks would enjoy eating any of our American snap bean varieties whether they were purple, red, black, or white if only they knew about them or could purchase or grow disease-free seed. In some countries of course these varieties are not adapted because of high soil acidity or length-of-day reactions.

Concerning our North American dry bean varieties, I'm fearful that most Latin American people would not accept our types. It is very difficult to change people's food habits, especially if they have been eating certain varieties for over 400 years. They desire their black, red, brown, and other colored beans and do not care to change. Neither would we. The type or strain depends on the area of the country. In some areas the Mulatinho or brown bean is most commonly consumed. In others the red bean or Rosinha is popular and in still others the black bean is most widely used. In Sao Paulo, possibly the most properous state in Brazil, the brown bean is most used. At Vicosa for several weeks we ate black beans twice a day on our rice. Other colored beans are various shades of tan, purple mottled, and dark purple. Size and shape of the seed are very important to the Brazilians.

Dry beans in Brazil. Dry beans are extremely important in the diet of most Brazilians and to many they are almost the sole source of protein. Average annual per capita consumption is 56 pounds compared with 7 in the US. Despite this, dry beans in Brazil are secondary to corn, coffee, rice, sugar cane, and other crops.

It is never certain that the bean crop will be as profitable as the primary crops. Yields are low because of poor seed, prevalence of disease, low fertility and high pH of the soils, unsatisfactory weed control, and competition with companion crops such as corn and sugar cane, with which beans are often grown. Actually beans rank fourth in importance, following corn, coffee, and rice. All farmers grow some beans but individual acreages are usually small. Beans are grown in small patches intercropped with coffee, cane, or corn. Most small farmers grow a sufficient acreage for their own needs and any excess is sold. Because of insufficient and poor storage conditions as well as inadequate transportation and marketing facilities, wide price fluctuations occur from one season to the next and as a result there is not a constant acreage. This frequently makes it difficult for the common man in Brazil to purchase sufficient beans which, together with rice, are his staff of life.

Brazil is the largest dry bean producing country in the world: in 1962 it grew almost 7 million acres of dry beans compared with slightly less than 1-1/2 million in the United States. Brazil's acreage was about 3/4 of a million larger than the combined acreage of the US and Central America and slightly over 6 million acres more than the combined acreage of Argentina, Chili, Colombia, and Peru.

Brazil's average yield per acre in 1962 was about 565 pounds, which is considerably less than that of the other South American countries except Colombia and slightly higher than the average for the Central American countries. Average yield per acre for the US is 1,247 pounds or about twice that of Brazil. Although this difference may not be due entirely to disease, it is assumed that much of it is. In 1962 Brazil produced over 35 million 100-pound bags of beans compared with 33 million for all of North and Central America, and slightly less than 5 million bags for all other South American countries. The United States produced almost 18 million bags.

In other words, Brazil grew over 4-1/2 times the acreage of the US but produced only about twice as many beans. It is my opinion that if certain bean diseases were controlled in Brazil, yields could be greatly increased. Improved cultural methods, the use of phosphorus and lime, better weed control, and lack of competition with companion crops would also increase yields.

Diseases of beans in Brazil. Among the reported diseases in Brazil the principal ones include anthracnose, rust, and common bacterial blight. Others of importance are the root diseases such as southern blight, Fusarium and Rhizoctonia root rots, angular leaf spot, and unidentified viruses. The diseases that cause less frequent damage are Alternaria, Ascochta, Cercospora and Phyllosticta leaf spots, powdery mildew, web blight, ashy stem blight, and white mold. Not previously reported in Brazil but now occurring in the Vicosa area and causing considerable damage is maucha gris leaf spot caused by a species of Cercospora. There are also 2 species of nematodes which infect beans. I realize that to many of you most of these latter diseases are unfamiliar, since many are not found to any extent in the US.

In central Brazil beans are grown during two seasons. In the first, or wet season, plantings are made from October through December with harvest following 3 months later. In the second, or dry season, beans are planted from January through March with harvest again coming 3 months later.

The important diseases of the wet season are anthracnose, white mold, and rust. Those of the dry season include angular leaf spot, powdery mildew, and rust. Rust is always present because of carryover of infected foliage, and particularly because large quantities of inoculum are present at the time of emergence of second-season plants. Consequently, they are infected in the seedling stage and suffer an early attack. Anthracnose is perpetuated by infected seed and by plant refuse. The disease requires high humidity for spread and development of the pathogen and thus is frequently not observed during the dry season because of a lack of proper environmental conditions.

The discovery of the New World almost marks the beginning of recorded history of the common bean. Not all varieties and types now grown in Latin America are indigenous there but many are. Beans were cultivated in the Americas long before the time of Columbus, for they were found in the pre-Columbian Andean tombs. Through centuries of cultivation, types and varieties have developed to meet needs. Similarly, it must be assumed that during this long period, resistance to certain diseases possibly evolved.

Disease-susceptible bean populations do exist in Brazil and are often completely susceptible to any one or more of the various diseases of the season. Yields as well as marketability are seriously reduced. Nevertheless, we believe resistance or a high degree of tolerance to a number of diseases or to certain of their races is present in many Brazilian bean varieties or types and probably several factors contribute. The first is that there are no commercial grades of beans in Brazil, as in many countries, and beans are sold by size and color. Each state or area grows specific types with uniform seedcoat colors which are demanded by consumers in that area. Thus lack of homozygous varieties for certain characters accompanied by whatever natural crossing occurs under field conditions continues to mix the populations of resistance genes and to select against susceptible genotypes.

Bean seed production and distribution in Brazil are not sufficiently developed for farmers to obtain suitable seed easily, as is possible in the US. Within recent years selected seed of some varieties have become available and distributed through state and federal agencies. Practically all bean growers plant seed from their previous crop unless, perhaps, an epidemic destroyed the crop. We can assume that much of the bean seed now used was probably produced on the same farm for many years. Natural selection in such populations provides continuity of selection within small geographic areas. Taken from their areas of natural evolution, these populations face new threats from different pathogens and from new strains of old pathogens.

Bean breeding programs in Brazil have been limited in scope and intensive improvement has been absent. Improvement to date has generally come from plant introductions. Dependence upon commercial varieties newly introduced from distant areas appears hazardous, especially if the varieties are pure lines. Such pure lines may fall easy prey to new races of pathogens that will build up so greatly on these lines as to endanger other varieties as well. Unadapted as well as disease susceptible introductions are not likely to be utilized further and present no problem. While worthy of trial, introductions must be handled with caution.

An introduction from Costa Rica, Rico-23, which is virtually a pure line, has been widely accepted in some black bean areas of Brazil but presents the aforementioned danger. A number of dry bean varieties from the United States including several of the Great Northern, pink, and pinto types, sanilac, Michelite, and red and white kidneys have been grown in Vicosa and none but the red and white kidney varieties are adapted. All of the varieties are disease susceptible, particularly to rust. This is not true of varieties from Venezuela, Mexico, and Costa Rica.

Bean breeders in Brazil should be advancing cautiously in their programs with respect to drastic varietal changes. Available to them, yet largely unexplored, is one of nature's greatest reservoirs of resistance--naturally selected populations. To "progress" and imitate the pattern of bean improvement through disease resistance as it has evolved in other countries would virtually imply that experience has no value. There is a great deal to be learned from the use of naturally selected populations for developing or for putting the "final touches" on a new variety. This variety may well be an assortment of various resistances which are instrumental to good production in a given area. Since beans are selected by consumers for size and color, the bean breeder is favored in his attempt to get resistance of various types into a composite variety. This could possibly be accomplished in 4 to 5 generations, whereas 9 to 11 generations are required to develop varieties that possess homozygosity for most characters.

My trips to El Salvador were made last April and again the early part of last month. I was accompanied on both by Dr. Floyd F. Smith, a USDA vegetable entomologist. Because of the alarming reduction of bean production in El Salvador since 1950, we were requested by Claud L. Horn of the USDA-AID Technical Assistance Program to make a survey of the dry bean growing areas to determine the cause of low yields and possibly to suggest ways of improving these yields. According to statistics of the Office of the Minister of Agriculture in El Salvador, the area planted to the three crops of beans in the 1949-50 crop year was about 29,380 hectares (73,000 acres) with an average yield of 1,062 K per hectare per year (950 pounds per acre per year). (El Salvador has 3 growing seasons per year.) In the 1961-62 and 1962-63 crop years the acreage was about 30,550 hectares (76,000 acres) and the average yield was only 660 K per hectare per year (600 pounds per acre per year). During the past 14 years total yields have been reduced from about 31 million K (682,000 hundred-pound bags) per year to about 20 million K (444,000 bags), a reduction of about

238,000 bags. Since about 1959 the yields during the dry season have been considerably larger than those during the wet season. It would be of interest to determine the reason for this difference.

During 1961-63 yield per acre for most of the other Central American countries with the exception of Costa Rica was slightly higher than for El Salvador. This was particularly true for Guatemala and Nicaragua, both of which, however, were far below the US figures. Average yield per acre per crop in the United States for 1955-59 was 1,178 pounds and for 1961 and 1962, 1,390 and 1,247 pounds per acre per crop, respectively, which is slightly more than 50% greater than the average acre yields per year in El Salvador.

Dry beans in El Salvador. Dry beans are very much needed in the diet of most Salvadorans and in many cases they are almost the sole source of protein. Average annual per capita consumption for the period 1959-61 was only 18 pounds or 77 calories per day. (This information and that listed below was supplied by the Western Hemisphere Branch of the Economic Research Service, U. S. Department of Agriculture.) Annual per capita consumption of other Central American countries for this same period was 12 pounds for Panama, 24.5 pounds for Costa Rica, 25 pounds for Nicaragua, 22.5 pounds for Honduras, and about 16 pounds for Guatemala. The per capita consumption for Mexico was about 46 pounds and for Brazil 59 pounds. It was reported that El Salvador is unable to produce sufficient beans for her needs and hence imports from 10 to 12% of their total consumption.

Because annual consumption of dry beans in the United States is only 7 pounds per capita, this food is only an incidental source of protein in our diet. Since the Latin Americans are so dependent upon dry beans for protein, the above figures show the extreme need to increase the acreage production of this crop not only in El Salvador but in all Central American countries.

Disease and insect survey. Only a limited survey was possible since it was made at the end of the dry season when many of the commercial plantings had been harvested. Actually, however, from our standpoint it was an ideal time, since the incidence of diseases and insect damage was at its height. Our observations were based primarily on bean plantings observed in the lower elevations where irrigation was available. Our surveys in the experimental bean plots at 2 experiment stations indicated that viruses were largely responsible for most of the crop loss. Damage from insects was also very serious. The most widespread virus appeared to be that of common bean mosaic or one of its strains. This disease is seedborne and is transmitted by aphids.

The second disease in importance produced symptoms somewhat similar to those caused by the curly top virus so common in parts of western US. This disease is probably related to the US curly top and not transmitted by the same species of leaf hopper that transmits the US strain. However, the presence of the beet leaf hopper (the vector of the US strain of curly top) may be revealed by further study. It is doubtful that the disease is seedborne.

The third disease, observed in plots at one of the experiment stations, caused a yellow leaf mottle somewhat similar to the symptoms produced by the bean yellow mosaic commonly found in the US. We feel, however, that no relationship exists between these two diseases. It is possible that this condition may be of a virus nature and possibly transmitted by the sweet potato white fly, from cotton which was growing in close proximity to the plots. A somewhat similar mottling was noted on the leaves of cotton plants near the planting and white flies in all stages were found abundantly on these plants.

Diseases of minor importance. The diseases of minor importance were fusarium root rot, bean rust, and angular leaf spot. It was very evident from the disease and insect survey that the principal reason for the low bean yields during the dry seasons was the widespread distribution of the two viruses mentioned before and to direct damage by leaf hoppers, chiefly, the Empoasca species, one of which causes hopperburn of beans in the US. Resistance to the common bean mosaic and the curly top-like viruses was observed in 2 varieties, Porillo No. 1, a small black shiny seeded type of local origin and a small, dull black seeded strain from Mexico. Apparent resistance to leaf hopper injury was also noted in Porillo No. 1. El Salvador requires 2 bean types for their commercial trade--a black shiny seeded type of moderate size and a similar-sized red shiny-seeded type. We feel that these can readily be produced through a breeding program which is now underway by the Salvadoran research workers. We at Beltsville have also made a number of crosses between Porillo No. 1 and several of our black and red American varieties which we will send to them for the selection of disease and insect resistance.

As mentioned before, in any Latin American bean breeding program a certain amount of heterozygosity or mixture of a number of characters is almost necessary for a new introduction or variety to survive. The release of homozygous or pure breeding lines would be a dangerous procedure. Such material could and would be readily wiped out by new races or strains of old pathogens because of their rapid evolution. The production of two and in some instances three bean crops in one year can readily bring about many new forms of organisms.

Probably a new bean variety for Latin American can be developed in 5 generations. At this time all characters would not be pure but the variety would be sufficiently homozygous or pure for seed size and color, disease resistance and plant height, which are the essential characteristics. By bulking a dozen or less of such similar phenotypic types a new introduction could be released in a relatively short time. Such a variety would survive under their conditions for a much longer period than would a pure line introduction such as is required before release in the US. These require from 9 to 11 generations. Ours is a much slower process, since we can produce but one and at the most 2 generations per year and only if the second generation is grown in a frost-free area such as southern Florida.

In El Salvador as well as in other Central American countries and Mexico, leaf hopper and other insect damage is very serious, especially in the lower elevations near sea level. In some areas we observed almost complete crop loss due to hopper damage. In one area damage from the bean pod weevil, an insect not present in the US, was causing from 25 to 40% loss before the crop was even harvested. Since dollars are not available for the purchase of insecticides and fungicides for pest control, breeding for insect and disease resistance is the only alternative. This is particularly needed for the warm humid coastal areas where the insect populations are extremely large. The former is being conducted in beans in Mexico with fairly good success. Tolerance to Mexican bean beetle and bean pod borer and good resistance to leaf hopper injury are being found. Such selections can be used in a breeding program in conjunction with the before-mentioned virus-resistant bean types for the development of multiple insect and disease resistant types.

During our recent survey, at the end of the rainy season, we found a somewhat different picture from that of last April which was the end of the dry season. The incidence of virus diseases was not as high as it was during the dry season and neither were certain insects as abundant. The latter possibly accounted for less virus disease transmission than in April. These diseases are insect transmitted. The pod weevil, however, was causing considerable damage in an area about 40 miles from San Salvador.

Angular leaf spot, a fungus disease which requires high humidity for its spread and development, was very widespread. Bean rust was less important. The bacterial blight diseases, anthracnose and other leaf spotting diseases, were not observed. The reason is difficult to explain. It is possible that considerable natural disease resistance exists in many of the native varieties which have been grown there for hundreds of years and as a result of the survival of the fittest many of the Latin American sorts are resistant. Some rssistance to angular leaf spot and rust was noted and these characters will be incorporated into the varieties possessing virus resistance.

El Salvador is about the size of New Jersey and in 1961 had a population of over 2-1/2 million people. At present it is much larger. It is the most densely populated of the Central American countries. With an annual consumption of only 18 pounds of beans per capita, it is very evident that a real need for increasing bean production exists, especially since beans are the only source of protein intake of the majority of Latin Americans. Corn in the form of tortillas is the only other food of the poor people, and believe me many are poor. The interest shown by the three Salvadoran researchers (a pathologist, agronomist, and entomologist) with whom we are cooperating in a bean breeding program was very encouraging. Genuine support and enthusiasm were also shown by the El Salvador Minister of Agriculture who fully realizes the need of a sound bean program. It is our belief that within a relatively few years real progress will be forthcoming and that several new disease and insect resistant varieties will be introduced by this team of workers. Any accomplishments that are made by this group should be applicable to all the lowlands of Central America except possibly parts of Panama. To our knowledge, this is the only well organized bean program in Central America. Mexico too has an excellent program in progress.

EXPORT MARKETS IN THE CARIBBEAN

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I am convinced that the overall future of the US bean business is closely allied to progress in Latin America. This area is the largest per capita consumer of beans in the world and as standard of living increases, so will bean consumption. Latin America is that part of this hemisphere south of our border, including the islands of the Caribbean. It is an area where tens of millions of families live for a year on $100.00 or less--where 50 million adults exist below subsistence level and 11 million children of school age are not in school. It has more than tripled its population since 1900. Upwards of 80% of the people are engaged in farming, but their productivity is so low it falls short of feeding the population. Vast tracts of land are not cultivated at all and tremendous areas are cultivated in the most primitive fashion.

Let us keep in mind that these agricultural products are the main source of income for the most of the Latin American countries. Each year they bring less income because price in the world market has gone steadily lower. Think of how their balance of payment suffers, since they must import industrial products at a price which increases yearly.

Take education. The problems are almost beyond belief. In Peru, for example, over 70% of the people are illiterate. This situation exists to a greater or lesser degree in many other countries. There are schools to be built; teachers to be trained; textbooks to be prepared; roads to be built in order to improve communications, and countless other reforms which would help only in eliminating illiteracy. The scope is actually broader. There are specialists to be trained in order to raise the quality and suitability of the people for competition in this modern world.

In most places there is no running water, and much less drinking water available than the normal supply as we know it. Sewage disposal is, naturally, nonexistent. Housing is a most acute problem. I have outlined just a few problems and whatever field you explore the problems seem almost hopeless.

Will the United States throw up its hands because the problem is serious? The answer is no, for three reasons: (1) We are often accused of being imperialistic, and materialistic, but basically we are humanitarians. (2) This area can become our greatest export market for goods and services. A meager 5 to 10% increase in the standard of living would have terrific impact on United States business, including the bean business. (3) Latin America must not fall into Communistic hands.

We in the United States are by nature impatient. We all remember what happened at the end of the World War II, when we were afraid that all of Europe would turn Communistic. We devised the Marshall Plan and we sent millions of dollars to rebuild Europe. Whenever we saw in the elections of a European country a high communist vote, we got impatient. But eventually, the Marshall Plan worked; it worked and we are proud of its accomplishments. The Marshall Plan was expensive. But because it worked, all would agree today that it was cheap at the price.

But, relatively speaking, what had to be done in Europe was a simple task. Industrial machinery had been destroyed and our dollars helped Europeans to rebuild their industries and their economy. In Latin America, however, we are starting from scratch. We are not rebuilding factories. We are putting up completely new factories. Workers must be trained. Markets must be created. The know-how must be provided.

We have in our favor something we did not have in Europe. We have a program known as the Alliance for Progress. This is a program, it is true, where the United States is spending substantial foreign aid funds. However, much more profound, much deeper than money, the Alliance for Progress is an expression of faith in the people of Latin America.

It must be remembered that we are not going to see results from one day to the next, from one year to another. Before giving economic aid to any of the countries, the United States insists upon a master plan, which in itself is a major undertaking. The last information I had, already five countries, Bolivia, Mexico, Venezuela, Chile, and Colombia, have prepared such plans. But all of them take time to put into operation.

The task ahead under the Alliance for Progress program is tremendous. Even today, a good portion of the money that is being spent is going into emergency measures rather than into development programs. There are countries whose condition is so critical that we must provide certain stop-gap grants, solely to prevent disasters. We are working against time, and we have to take emergency measures, but we cannot accomplish the task in as short a time as we would like to. It would be wonderful if by means of a crash program we could correct every situation in a predetermined period of time.

Take a look at Puerto Rico where for years the USA has contributed vast sums to improve the standard of living. Twenty years ago, Puerto Rico was known as "the stricken land," "the problem child" of the United States. With no natural resources, an agricultural economy which depended mostly on one crop, sugarcane, the future of this extremely overcrowded island seemed hopeless. The result of overpopulation was a very low per capita income, and a lopsided distribution of wealth. However, in only 20 years, Puerto Rico's outlook has changed completely. It is an island of 2,300,000 using 500,000 bags of beans annually.

In the Caribbean, except Cuba which I am sure we all have written off, the Dominican Republic, with a larger population than Puerto Rico, is the one major island offering bean volume potential. It could become a second Puerto Rico provided the necessary changes come about. Communist activity is prevalent! Temporarily, it is lost as a bean market if the report we recently received holds--which reads as follows: "As of November 18th a new law has been passed levying a 50% ad valorem tax on the importation of beans and this effectively terminates their importation unless there is some change."

And so, Gentlemen, I sum up what I have told you very simply. We have the program of the Alliance for Progress which, in spite of its imperfections, in spite of its shortcomings, is basically a sound program that we must back up, and we have to back it up with understanding. Let us not be impatient. Let us have faith that we are going to win.

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