An Historical Perspective On Significant Accomplishments in Dry Bean Research -- The First Hundred Years-- M. Wayne Adams, Ph.D. Professor Emeritus, Michigan State University

The idea for this perspective arose in the minds of my former colleagues, Drs. George Hosfield and Jim Kelly, of the USDA and Michigan State University, respectively, who selected me and this topic, partly, I suspect, because they fantasized that possibly I had been around some hundred or so years ago when the first instances of bean research occurred.

In reality, of course, it was not I who was around at that time but my grandfather, Leisander Adams. My earliest recollection of personal involvement in "bean research" came as a five-year old lad helping my father pull and thresh the beans from a small patch of viny white soup beans grown for home consumption on our family farm in Parke County, Indiana.

To be specific, it was a little over 100 years ago, in 1889, that bean anthracnose was formally recognized as a serious disease of beans in Michigan, and the causal organism identified. This discovery was made by Professor of Botany W. J. Beal of Michigan Agricultural College. Beal is better known as the first person to observe hybrid vigor in the first generation of the cross of two varieties of open-pollinated corn.

A plant pathologist in New York in the early 1900's discovered races in the organism causing anthracnose, and found evidence of resistance and susceptibility. Since then, the number of races has increased greatly, and various genetic systems regulating reaction to the disease have been discovered. One of the more prominent of these is the ARE gene, which confers resistance to several races of the organism, and most recently, the discovery of molecular markers genetically linked with the ARE gene.

It was observed by my predecessor at Michigan State University, Dr. E. E. Down, and Dr. Axel Andersen, his plant pathologist coworker, that the navy and tropical black beans with which they worked were generally susceptible to the race of anthracnose, but resistant to the beta and gamma races.

In their minds, and mine too as I became involved in the Michigan program, this situation aroused no particular intellectual curiosity. Had we but known, we were seeing the manifestation of the uniqueness of the Andean and Meso-American gene pools and of co-evolution of host and pathogen genotypes in those major gene pools. Co-evolution has now been impressively documented in work reported by Dr. Pastor-Corrales of CIAT, not only for anthracnose but also for angular leaf spot, and independently for the latter disease by work of the Bean/Cowpea CRSP Malawi project.

The first confirmed specimen of common bacterial blight in beans was collected in 1900 by Dr. F. C. Wheeler of Michigan Agricultural College. For most of the next 75 years, common blight has been a serious problem for bean growers in the North-central U. S. , and essentially intractable insofar as breeding for resistance was concerned. Chemical treatments were found ineffective. Dr. J. H. Muncie of Michigan Agricultural College suggested in 1917 the growing of beans for seed in the semi-arid Western states in order to control seed-home diseases. This practice, which continues to the present day, probably has been the salvation of commercial bean production in the North-central region.

Genetic resistance to common blight did not become a reality until the work of Coyne and Schuster beginning in the 1960's in Nebraska. Their source of resistance genes was derived from the Tepary bean by way of an inter-specific cross made initially by Dr. S. Honma at Nebraska. A selection from Honma's cross, Great Northern #1-27, was used by Coyne to produce several Great Northern varieties with tolerance to common blight.

Except for a couple of isolated cases where single genes for resistance were postulated, blight resistance has been attributed to quantitative gene action. Thomas and Waines of the University of California at Riverside have reproduced the common bean by tepary cross, and from their material has come a second array of lines, the Xanlines, carrying genes for common blight resistance. Recently, a molecular marker has been found associated with one of the quantitative trait loci that contributes to this blight resistance.

The most genetically variable pathogen of beans is the rust organism. Rust is a world-wide problem in beans and many bean breeders, pathologists and geneticists have contributed to the rust literature. In the U. S. , the contributions initially of Dr. W. J. Zaumyer and more recently of Dr. J.R. Stavely of the U.S.D.A. at Beltsville, together with colleagues in Puerto Rico and North Central Experiment Stations, have been especially noteworthy.

In addition to the multiplicity of rust races identified by this group, they have shown that resistance to a number of races can be traced to closely linked sequences of dominant genes. It has been reported recently that some 31 USDA Plant Introductions carry linked dominant genic complexes conferring resistance to all 66 rust races currently maintained in the permanent collection at Beltsville.

I have not done the statistics on this matter, but I speculate that one could probably discover a positive correlation between the number of rust races showing up over time and the number of rust pathologists active in the field.

There are other diseases affecting beans with respect to which significant research has been done. Among them are the successful development of Fusarium root rot resistance in snap beans in Dickinson's program at Geneva, and Bruce's red kidney program at Prosser.

White mold is currently probably the most intractable disease of all, and one capable of devastating potential in the North-central region of the U. S., particularly. Architectural avoidance offers some protection, but physiological-genetic control that is stable across the region is urgently needed. Ex-Rico 23, a Type III navy cultivar, descended from a Brazilian black bean, possesses a characteristic of its flowers which provides some resistance to the establishment of white mold infection in the field. Both the breeding programs at Geneva, New York in snap beans, and at Fargo, North Dakota in dry beans, have produced lines with useful levels of tolerance to white mold, but complete resistance has not yet been discovered. The search must continue. Personal experience in Michigan assures me that architectural avoidance alone cannot be relied upon to protect a growing crop from white mold damage.

It would be remiss of me to overlook common bean mosaic, but I would like to discuss accomplishments with this disease , in part, in relation to early variety development in Michigan. I realize there must have been bean variety development in some fashion at places other than Michigan in the early 1900's or before, not counting the contributions of numerous individual seedsmen and farmers. Michigan Agricultural College, the first of the Land Grant colleges, was also the first institution in the U. S. to employ a full-time plant breeder. This occurred in October of 1906, with the hiring of Mr. Frank Spragg. In 1908, Spragg selected a single disease-free plant out of a mosaic-infected field of commercial navy beans. This led to the release in 1915, after increase and testing, of the navy variety, Robust. Spragg did not know until 1918 that he had selected a plant that carried a recessive gene for immunity to strain V-1 of common bean mosaic. Mosaic had first been reported as a disease of beans in 1916 in New York.

The story of V-1 resistance in Robust tuned out to be merely the prelude as far as BCMV was concerned. In 1943, both in New York and Idaho, a new strain of mosaic made its appearance. This strain became known as V-15. Subsequently, many more strains have been detected and sources of genetic resistance identified. The classic work of Drifjout in the Netherlands in 1978, clarified for bean breeders and pathologists the genetics of the host-pathogen system in BCMV infection.

Molecular markers have now been discovered for certain of these genes, and this will enable breeders to assemble the combination of resistance factors required for protection against a wide array of virus strains.

Let me return now to the variety development program of Professor Spragg. The first artificial crosses in Spragg's program were made in 1916-17 by a graduate student, G. W. Putnam, who began crossing the Robust navy bean with the Wells red kidney in order to enhance the anthracnose resistance of both types. From the historical perspective this is significant for at least two reasons: It represents the first known attempt at pyramiding genes for resistance to a disease, b= race resistance from the navy gene pool combined with race resistance from the red kidney. By 1923, about a dozen highly resistant recombinant types had been turned over to Spragg and his young assistant, Eldon Down, for agronomic evaluation. Spragg and Down had hoped to obtain a navy bean immune to both anthracnose and mosaic from this cross, but for reasons not stated in their annual reports they never succeeded in this goal. (This objective was reached some 33 years later with the release of the Sanilac navy bean).

In 1924, Professor Spragg was killed in a car-train accident near the campus of Michigan Agricultural College, and E. E. Down took his place as plant breeder.

Now, the second reason for the significance of the Robust by Wells kidney cross: This cross brought together a representative of the Meso-American gene pool, Robust navy, with a representative of the Andean gene pool, the Wells Red Kidney. I am convinced that neither Spragg nor Down realized the importance of this at the time. It is now known that such inter gene-pool crosses often fail or lead to sub-viable offspring, due to the bringing together of two complementary lethal genes, Dl1 and Dl2, in the hybrids, one gene from the Meso-American gene pool and the second from the Andean gene pool representative. The elucidation of this system is a noteworthy accomplishment by any criteria.

The fact that Spragg and Down were never able to derive any agronomically useful recombinants from their Robust by Wells Kidney cross can be attributed, in all probability, to the genetic misalliance of an inter-gene pool combination.

A significant advance in navy bean breeding was achieved by Dr. Down, together with his plant pathologist coworker, Dr. Axel Andersen, with the production and exploitation of the X-ray bush mutants derived from the Michelite navy bean. Michelite, a product of Robust by Early Prolific, had been released by Down in 1938. In that year, graduate student Clarence Genter used x-rays on dry seeds of Michelite, a full-season, nonclimbing vine plant type. Down grew out the M2 and M3 generations of Genter's material in 1940 and 1941. Among the many mutants observed was a small upright, non-vining plant that matured some 10 days earlier than Michelite. Down hoped to develop a disease resistant high yielding early maturing vine bean from backcrossing this mutant to Michelite. He was never able to achieve this objective.

In all the backcross families produced, earliness was always associated with the bush (determinate Type I) growth habit. What he did accomplish was to gradually increase the vegetative vigor of the bush segregants.

In 1948, Andersen joined Down and the focus of the Michigan program was shifted in the direction of multiple disease resistance. Having failed in his initial objective of getting an early maturing vine type, Down decided to accept what his breeding populations seemed inclined to give him, namely, early maturing vigorous bush type plants. According to Andersen, Down had the idea at this time that an early upright bush type variety might allow growers to combine the crop directly in the field, obviating the need for pulling and windrowing. This was a noble idea, but Alas!, this too was not to be.

Per they proceeded with the task of incorporating anthracnose and mosaic resistance into a-n early maturing bush, and in 1956 released the navy bean, Sanilac, which turned out to be a very successful variety. Within about five years of its release, Sanilac and its sister releases, Seaway, Gratiot and Seafarer, completely replaced Michelite in the bean fields of Michigan. Sanilac was the first example in the U. S. of a mutation-based crop variety. The Atomic Energy Commission, in 1961, made a documentary film of the story of the development of this variety. Unhappily, Dr. Down passed away in December of 1957, and did not live to savor the fruits of his greatest accomplishment.

I came along at the end of 1958 as successor to Dr. Down, and together with Andersen, was able to release the Seaway, Gratiot and Seafarer varieties, all of which were based upon the x-ray mutant. Having shown their superiority over the late maturing vine type Michelite, these varieties spread out from Michigan and at one time were grown in several foreign countries.

One reason, I feel, for the wide adaptability of these particular Type I varieties, architecturally distinct, I might add, from the Type I kidneys, was their insensitivity to photoperiod. Flowering remained temperature-dependent, however.

One of several investigators long involved in photoperiod genetic research, Dr. D. Wallace at Cornell, has made a compelling case for the view that genes regulating photoperiod response have a major influence on partitioning of photosynthate in bean plants. The switch from vegetative to reproductive growth, to the extent that it is a complete transition, affects biomass accumulation, partitioning ratio, and days to physiological maturity. At the level of crop physiology, these processes are the primary components of yield.

My personal bias, however, persuades me that the search for higher yielding genotypes should not end with the photoperiod genes, per se. I think many in this audience are old enough to remember along with me a remarkable genetic and agronomic achievement called the "Green Revolution". The outstanding yield improvements made in rice and wheat depended on a complex of factors, but chief among them were photoperiod neutrality and a particular mode of plant architecture, the semi-dwarf, not to exclude fertilizer responsiveness and pest resistance.

Was any kind of a "Green Revolution" possible in dry beans, even a small one? A notable transformation of bean production had been achieved with the introduction of the x-ray bush mutant-derived navy varieties. But their yield was not really much improved over the old Michelite; earliness, yes; disease resistance, yes; seed quality, yes. But, yield - marginally, if at all.

Working with these Type I populations in the 1960's, I was forced to conclude that we were not making progress as far as yield was concerned. The lessons of the dramatic yield improvements in rice and wheat, and a remarkable paper by C. M. Donald, an Australian wheat breeder, in which he introduced the concept of a wheat ideotype, got me thinking along lines of further architectural changes in navy beans.

Eventually, the concept of a bean ideotype was formulated and presented at the CIAT Symposium in Cali, Colombia, in the early 1970's. Architecturally, the bean ideotype was represented simplistically as a single stout central axis with a small number of erect basal branches, with from 10 to 14 internodes each, with flowering racemes at each node on each axis. It was conceived that the plants should be relatively tall (taller than the bush types), with orienting small leaves to permit light penetration, lodging resistant, narrow in profile to promote growing in narrow rows at relatively high plant populations, and amenable to direct combine harvesting. A key ingredient in the ideotype was the concept of the source-sink unit, defined as a section of stem consisting of a node, the associated trifoliate leaf, and the flowering raceme in the axil of that leaf. The classic anatomical study done on the bean variety Black Valentine in 1927 provided evidence of vascular traces connecting a leaf and its associated axillary pods.

Such a plant structure did not exist in any U. S. grown dry bean cultivar at that time, although the resemblance to soybeans was obvious. A reasonable facsimile did exist, however, in certain bean varieties indigenous to Central America, the Type III Tropical Blacks. Attention was drawn to this gene pool by a strain known as NEP 2, a white-seeded mutant of the tropical black variety San Farnando, produced by C.C. Mho at Terrible, Costa Rica, by OEMs treatment of dry seeds. GNP 2 possessed many of the architectural features of the proposed ideotype, and these have proven to be highly heritable in crosses with traditional Michigan navy beans.

A marked increase in yield potential, particularly in narrow rows, in yield stability, and resistance to certain biotic and abiotic stresses have resulted from the introduction of the Type 11 germplasm into U.S. navy and black bean varieties. The ideotype concept, based on Type 11 germplasm, has been applied successfully to pinto and great northern breeding at Michigan State University and is being incorporated into variety development in other programs here and abroad, according to recent reports.

As for Michigan and the influence of Type 11-derived varieties of navies and blacks upon production, the last half-dozen years have seen a steady rise in state-wide average bean yields per acre, from a more or less long time static level of some 12 to 13 cwts/acre to near 16 cwts for the early 1990's, and 18 cwts in 1995. Both biased and unbiased observers attribute this increase primarily to the widespread growing of the "upright short vine" type varieties, that have almost completely replaced the Sanilac-Seafarer type culltivars.

Coming down to the last decade or so of bean research, I will note briefly several special areas where important contributions have been made. Since these areas are, for the most part, outside my personal professional experience. my comments may not do them the 'justice they deserve. However, I would like to express my admiration for the work that has been done.

I would recognize the work of Dr. Colin Leakey in his efforts to interpret and consolidate the results of mostly European geneticists having to do with seed coat color genetics and the related biochemistry into a more comprehensible picture. It occurs to me that Dr. Leakey is one of the few geneticists in our field who carries the proper intellectual genes for undertaking such a daunting task.

We must admire the studies on bean protein, specifically the phaseolin fraction, which, in the hands of the Wisconsin group, starting with Bliss and Gepts and continued by Gepts and coworkers, has led to our present understanding of major gene pools, a very significant accomplishment, indeed.

I should like to recognize another area at one time almost wholly neglected by most bean researchers, namely, biological nitrogen fixation. Bliss and his students at Wisconsin are responsible for demonstrating differential efficiency among cultivars in N-fixation, and for showing its hereditary dependence. Peter Graham, at CIAT and the University of Minnesota, has concentrated on the role of Rhizobium and the differential ability of Rhizobium isolates in the N-fixation process. I am not aware of any active breeding programs in the U. S. where N-fixation efficiency is a significant objective.

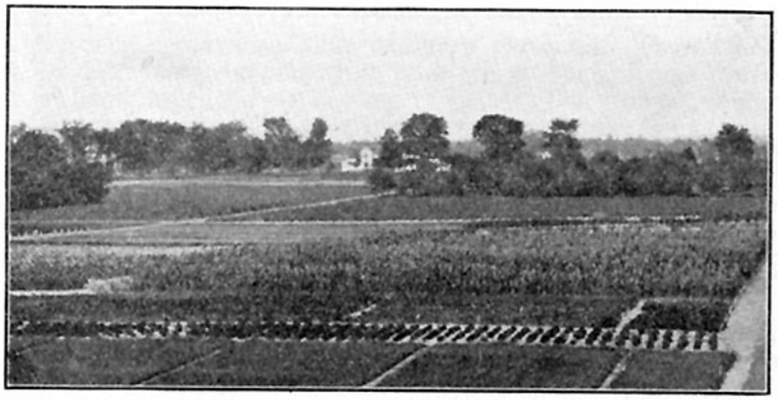
The gene pool studies have been expanded to wild Phaseolus vulgaris (in its various ecotypes by Freytag, the taxonomist, turned breeder, turned evolutionist, and by D. Debouck and associates at CIAT, Mexico and the U S., including the Kaplans of the University of Massachusetts; collectively their work is opening up a wholly new and exciting chapter on the origin and domestication of the common bean.

The large and important area of bean protein quality and digestibility, starting with the work of Bressani and colleagues of INCAP in Guatemala, and of processing quality characteristics, the latter investigated by Hosfield and Uebersax and their students, represents another significant dimension to bean improvement. I should note also the research on flatulence, which has focused upon the oligosaccharides in bean seeds since the pioneering work of Steggerda at Illinois and Murphy and colleagues at the former USDA laboratory at Albany, California.

I salute the development of linkage maps in beans. Many investigators contribute to the data base for mapping the bean genome; Mark Basset of Florida and Paul Gepts of the University of California at Davis have taken leading roles in this very fundamental activity. Bean varieties will come along, play their part, and fade away, to be replaced by better ones. The linkage map is forever; it can only get better.

Finally, just in the past four or five years, with the development of the Random Amplified Polymorphic DNA (RAPD) technique, several workers have begun to tag genes of economic traits using these molecular markers. The markers not only contribute to the data base for chromosome mapping, but provide the breeder with more powerful tools for selection purposes. This will undoubtedly expand in the future.

It was suggested to me that I should conclude this presentation with some crystal ball predictions for the future in bean research. Frankly, I no longer feels qualified to undertake such a task intelligently. Let me tell you how my last prediction turned out. In the middle 1960's, Dean Cowden of the College of Agriculture at Michigan State University set before the faculty the task of forecasting the shape and status of agriculture in Michigan as it might appear in 1980. My particular responsibility included predicting the average bean yield for the state by that time. In my optimism and naiveté-none of us dared be pessimistic-and after consulting with my associates, who also were optimistic, I arrived at the figure of 18 cwts/acre as our anticipated state-wide average yield. I missed by about 15 years. I do not believe my reputation can stand another prediction.



BIRTH PLACE OF ROBUST BEANS
The original plant grew in the short rows of beans shown on the Michigan Experiment Station test plats in foreground (1908)

Fig. 14. Building good bean stacks with a form.
a — Setting up the form.
b — Filling the form with beans.
c — Removal of the two sections.

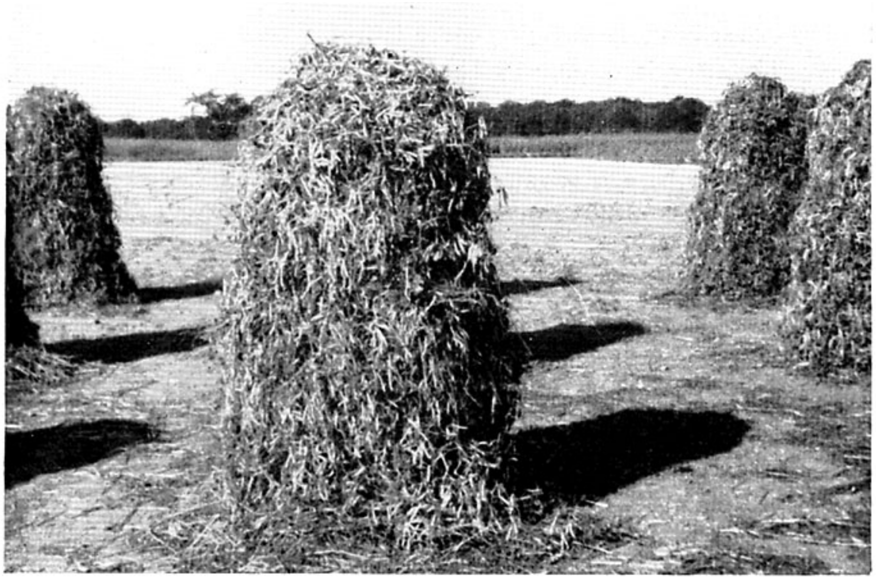


Fig. 13. Well built bean stacks set just off the field to permit timely planting in wheat.

Fig. 3. Threshing small plots of beans. The nine plots of each variety are assembled and stacked in order, a layer of straw keeping each one separate. The beans are allowed to dry in these stacks until they are ready to be threshed.

Source: Michigan State College, Agric. Expt. Station Special Bulletins 108, 295, 329