STRATEGIES, ACHIEVEMENTS AND CHALLENGES IN BEAN RESEARCH; THE CIAT PERSPECTIVE

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Introduction

National and international bean research programs have been engaged in past years in developing improved common bean varieties and production practices. Considerable progress has been made in certain research areas, yet, despite concerted efforts, progress is lacking in others. This paper briefly highlights past research strategies, including major achievements, or lack thereof and proposes some strategic changes to meet future challenges. Since research, done by CIAT and the CRSP greatly influences national programs in developing countries, a periodic and critical evaluation of these international efforts, and how they relate to each other, is highly appropriate.

Crop Background

Dry beans, Phaseolus vulgaris L., originating in the medium elevation mountain ranges of Meso-America and South America, were distributed worldwide by early colonizers.

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Current annual bean production in the tropics amounts to about 4 million tons in the New World, 1.5 million tons in Central Africa and about 0.3 million tons in West Asia, and North Africa. Total production has increased over the last years, but this increase was mostly due to area increases. Beans have been increasingly forced to more marginal agricultural land, to make room for more profitable crops.

Beans are an important subsistence and cash crop, especially in rural areas. Per capita bean consumption is highest in Rwanda and Burundi (about 40 kg/person/year), and is about half that rate for the two leading producers in the Americas, Brazil and Mexico. In Rwanda and Burundi one third of total protein intake is from beans. In the tropics, consumption of green or snap beans is substantial. Bean leaves are also consumed in Africa.

Most beans are produced by small farmers, many of whom are women, and who are often unable or unwilling to use inputs to increase production. Typically, beans are produced in association with other crops, mostly maize, and in many different production systems. Beans are also attacked by a large number of pathogens, many of which are seed-borne. These factors keep productivity low, at around 550 kg/ha, although total crop return per hectare is higher. Bean monoculture equivalent yield in the tropics is estimated at around 800 kg/ha. Beans are also produced in monoculture under high input conditions, mostly in coastal Mexico, Chile, and Argentina, where yields are relatively high. In Chile, yields average around 1t/ha, but in some years they have gone as high as 1300 kg/ha (FAO Production Yearbooks).

PAST RESEARCH EMPHASIS: WORLD WIDE

Bean production constraints are numerous; nevertheless it is generally agreed that diseases and insects are the most destructive. Drought and infertile soils rank high, too. The bean literature, in CIAT's world-wide bean documentation centre reflects this hierarchy. Of the 6798 bean documents (published papers, research reports, etc.) processed to date, 1629, or 24.0%, are concerned with diseases. Agronomy publications make up the second most important research area, covering 1444 or 21.2% of all articles. Genetic improvement, in third place, covers 637 or (9.3%) of the articles. Articles referring to bean research for human consumption trail far behind with 254 documents (3.7%). Of the articles on genetic improvement, 34.6% involve breeding for disease and insect resistance. About 27.1% of all breeding articles involve yield breeding; which means, only 2.5% of all documents in CIAT's documentation centre discuss yield breeding!

The emphasis on breeding for disease resistance is probably stronger than the statistics indicate. In the past, much effort was directed towards breeding early maturing varieties. Early maturity would shorten the crop's exposure to diseases and insect pests. Admittedly, there were other reasons for developing early maturing varieties, including: to fit beans into a crop rotation cycle, or climate cycle; to catch the early market high prices; or to provide food as early as possible after the dry season.

CIAT STRATEGY

From its formation in 1973 CIAT's Bean Program has placed most emphasis on breeding for tolerance to stress, principally disease resistance. Surveys justified this emphasis. Two studies support this conclusion: a survey in Colombia in 1974-75 identified diseases and pests as the main production constraints both of small and large farmers (Ruiz de Londoño et al, 1978). A second study of a large on-farm project to improve maize and bean yields in Honduras (PROMYF) concluded that the use of fertilizer or other inputs was too risky until a more disease-resistant bean variety became available.

The CIAT Long Range Plan, (CIAT 1981), gave highest priority to disease control research. At the beginning of the 80's, about 80% of CIAT's total crosses involved disease resistance. In 1984, for example, the CIAT Bean Program made 4163 new hybrid combinations. Of these, 79% were made to obtain multiple disease or insect resistance, to improve grain type, or to create levels of variation not found in the gene bank. Over one third of these crosses were done to obtain higher levels of disease resistance; only 12.5% were specifically intended to improve yield potential and architecture. The basis of the priority to develop disease resistant varieties was: the small-farmer nature of the crop; the widespread importance of diseases; the fact that most diseases are seed-borne and persist because farmers usually save their own seed; and due to the difficulty to control diseases by any means other than by genetic resistance. Throughout the 1970s, CIAT's bean breeding efforts concentrated on controlling diseases through the development of multiple- disease resistant varieties. Priorities were given to Bean Common Mosaic Virus (BCMV), Rust, Common Bacterial Blight (CBB), Anthracnose and Angular Leaf Spot. We believed that a multiple disease resistant variety would reduce production costs, especially production risk, and stimulate farmers to further increase yields through increased inputs.

CRSP STRATEGY

The Bean/Cowpea CRSP was formed to support research on these two basic foodcrops in the developing world. Of the 18 projects which form the global plan of this CRSP, 12 involve dry beans. Five of the bean projects (42%) are specifically devoted to the development of disease resistance.

In the 1984 CRSP Annual Report, 151 articles, reports or presentations are listed of which 30% discuss bean diseases and pests, and only 2% yield potential. Clearly the CRSP, like CIAT, is strongly biased towards pest and disease control through genetic resistance.

THE PRINCIPLE OF COMPLIMENTARITY

Bean research is sometimes divided into two broad categories: character improvement and character recombination. The former is the development of parental material with a high level of disease resistance, yielding ability, etc. The latter, in the form of commercial varieties, combines this superior germplasm with agronomic and consumer requirements. While character improvement mostly involves basic research, character recombination (or character deployment) is mainly applied research.

CIAT's Bean Program emphasizes applied research (character recombination). It adapts the developed world's knowledge about bean growing to the tropics, and combines it with the best knowledge found in the bean producing countries. Obstacles encountered in the research process are often solved by seeking help from basic research institutes, such as universities in the developed world and in the tropics. This form of applied bean research concentrates on the development of improved germplasm, and its accompanying agronomy promoted to farmers through national programs. CIAT training programs for national research program personnel help the latter develop and promote new technology to farmers.

CIAT recognizes the CRSP as an association between US universities and developing countries designed to improve food production. The CRSPs are mainly concentrated in universities where the principle orientation is towards basic research (character development). Progress in basic research allows more rapid progress in the area of applied research, such as is conducted mainly by the national programs and CIAT.

CIAT and the CRSP are largely complimentary. The Memorandum of understanding signed by both institutions spell this out clearly. Nevertheless, if either program, CIAT or the CRSP, would deviate from the sphere of its comparative advantage (CIAT concentrating on basic research or the CRSP being over-involved in varietal development and promotion) duplication and waste of resources would result.

USAID has reserved a small IARC-targeted budget for Special Constraints Research by US institutions. This progam precisely fits the principle of 'comparative advantage'. US universities geared toward basic research would be financed to resolve bottlenecks IARC's encounter in their applied research programs. Applying the comparative advantage principle, this new AID initiative would well fit within the CRSP crop mandate.

The establishment of research ties between US universities and CIAT is difficult due to restrictions on the use of US federal funds to travel to Colombia. Such has not been the case with European agricultural research centres which have increased their Bean Program support through several collaborative basic research projects.

In summary, at CIAT we believe that the CRSP and its sponsors should recognize that the goal of improved nutrition requires both basic and applied research. Efforts to make the CRSP projects impact directly on national program production are understandable and humane but, nevertheless, they may prove duplicative and should not be encouraged. Similarly, CIAT should not enter the area of basic research, unless no solutions are available from outside.

ACHIEVEMENTS IN RESEARCH AND TRAINING

Progress in research and training over the last decades has been impressive. This is specially so when we take into consideration the relatively small body of researchers investigating beans or cowpeas, as compared to crops such as maize, wheat or soybeans.

1. Over the past 10 years CIAT's training has created a strong research capability in the national programs to control diseases through resistance breeding, and to a lesser extent through integrated disease control. Of 572 national program scientists trained at CIAT from 1973 until now, 159 (27.8%) were trained in pathology (excluding production training). Those trained in breeding were mostly involved in breeding for disease resistance and, if included, would raise the percentage of scientists trained in disease control to 50.4%.

2. The six CRSP projects and CIAT, both involved in disease resistance breeding, have strengthened university and national program potential to control diseases. The CRSP-sponsored degree training is highly beneficial and is most appreciated at the national program level. This training will have a continuing positive effect on future research.

3. Significant progress has been made in the development of multiple disease resistant germplasm. Since 1979, most CIAT coded lines are BCMV resistant. The race variability and inheritance of resistance is well understood, enabling US and CIAT bean researchers to resolve the problems of necrotic strains in the USA, and deal with blackroot in Africa in a relatively short time. Anthracnose resistance is abundantly available; pathogenic variation has been studied and many new races have been identified, and bean genotypes with wide resistance are available. There is no evidence that the fungus has formed new races, overcoming resistance sources. New resistance sources to common bacterial blight (CBB) have been identified from crosses made by CRSP scientists between <u>P. vulgaris</u> and <u>P. acutifolius</u>. Screening methods for CBB are well

developed, and additional resistant parents have been identified. Angular leafspot, though, is one of the least researched major bean pathogens. Recent research has clarified the pathogen's race distribution and resistant germplasm has been identified for different bean producing regions. The International Bean Rust Nursery has identified many sources of germplasm with ample and more stable resistance. The small rust pustule type, characteristic of some bean accessions, is especially promising, as it influences yield less than the large pustule present on susceptible varieties. A standard evaluation scale for rust has been established. Many examples of research progress can be cited for other bean diseases and pests. Such as: upright architecture to avoid whitemold; integrated web blight control strategy; new sources of non race specific resistance to the halo blight pathogen; etc. Numerous other examples could be mentioned to highlight the impressive research progress that has been made to control bean diseases through varietal resistance.

4. Research on insect resistance, drought tolerance and nitrogen fixation, despite limited efforts, has made considerable progress. Resistance to seed-infesting bruchids has been found in wild, uncultivated forms and is being incorporated in commercial cultivars. Bean pod weevil and Mexican Bean Beetle resistance has been identified and used in crosses. Drought tolerance identified so far in beans seems to be mainly related to the ability of bean genotypes to root deeply. The ability to fix atmospheric nitrogen was transferred from tropical germplasm into temporate material.

5. Many national programs have released disease resistant germplasm. Guatemala has greatly increased production and productivity with BGMV tolerant varieties; self-sufficiency in beans has been achieved and prices are down. In 1984, Argentina's net production increased US$2.1 million by planting new BCMV, anthracnose and BCLMV resistant varieties. Costa Rica may have reached self-sufficiency in beans through the use of multiple disease-resistant varieties. Cuba released ICA-Pijao, which is resistant to BCMV and BGMV. Other examples could be cited where disease resistant varieties have had an impact on production. However, it is too soon for FAO statistics to reflect those achievements.

6. Many more research achievements, some probably even more important than the ones listed, could be cited. It is obvious that a great deal of research progress has been made over the past years.

NEED TO REEVALUATE RESEARCH STRATEGIES

In the past 45 years, research in the US has doubled or tripled yields of such crops as wheat, soybeans, maize and sorghum. Soybean breeding over the last 75 years has increased yields through new varieties by 47%, or a yield gain of 18.8 kg per year through genetic improvement alone (Burton, 1981; Specht and Williams, 1984). A significant proportion of this yield increase resulted from hybridization in the mid fourties after widening the genetic base (Specht and Williams, 1984), despite the problem of photoperiod sensitivity in soybean germplasm. In another legume, peanuts, yields went up 4.6 fold in 25 years of research in Georgia (from both improved varieties and agronomic practices). However, in the last 45 years of research in the US, only a very modest dry bean yield increase was achieved. (FAO, Production Yearbooks; Fig. 1).

While great progress has been made in bean research, it is generally not reflected in increased yields in the USA or in the tropics. The reasons for this are diverse. Disease resistance may have been overcome by new pathotypes (e.g., for rust) or by the introduction of new strains (e.g., BCMV blackrot into the USA). Earliness is associated with reduced yield potential, and beans, especially in the tropics, have been moved to more marginal land. Past research may have stabilized yields, but one firm conclusion can be drawn: this research did not increase bean yields significantly.

CIAT's ten years of genetically improving beans has made substantial progress in breeding for disease resistance, upright architecture, insect resistance, etc. A significant increase in production has been made in several countries. However, in the IBYAN and other yield trials, the best black seeded CIAT lines show no higher potential for yield than elite bean varieties such as ICA Pijao or Jamapa, superior varieties developed by national programs before CIAT's formation (Table 1). Similarly, Brazil's leading cream striped variety, Carioca, still ranks among the top yielders in most yield trials. During years of little disease pressure, or in high yield areas, CIAT developed germplasm does not offer a yield advantage over traditional varieties (Table 1). However, during wet, disease intensive years, CIAT lines outperform local checks. We realized, therefore, that a change in research strategy was called for by placing greater emphasis on yield potential, as spelled out in our Medium-Term Plan (CIAT, 1985).

The decision to plant beans depends on the advantage a farmer expects from them over other crops. If we only include legumes as alternatives, significant research progress in those legumes will affect the competitive advantage of beans. In chickpeas, far example, new, upright, late maturing, high yielding, Ascochyta leaf blight-resistant varieties will form a very attractive alternative in many areas where both crops are grown (see ICARDA Annual Reports). Other examples could be cited, where the lack of research progress relative to other crops, has resulted in loosing ground.

It is, therefore, time to critically rethink bean research strategies. We at CIAT have concluded that the following three areas will need increased attention:

FUTURE RESEARCH NEEDS

1. Yield Potential. Initially, yield potential needs to be increased in irrigated areas where diseases and other stresses play an insignificant role. Next in areas where farmers have adopted disease resistant varieties. Yield potential is related to disease resistance breeding. If two varieties with equal levels of disease resistance are subjected to the same level of disease pressure, then the one with the highest yield potential will yield most. We assume that the biological mechanism causing the disease resistance does not reduce yield. In addition, research on other crops has created an increasing need to raise the yield potential of beans. Neither research in the US, nor at CIAT has identified the factors that could increase bean yield. Methods to raise

bean yielding ability are simply not available at this time. It is, therefore, my firm belief that the principal factor which will determine beans place among world crops in the future will be based on whether or not their yield potential under stress conditions can be raised. Research, however, should start with raising yields under no-stress conditions.

2. Adaptation of Tropical Germplasm. Beans originated in the tropics. The inability of tropical germplasm to adapt to higher latitudes has hindered US and European breeders from utilizing the full broad genetic variability. This is illustrated by a statement of the National Academy of Science (1972); ... "that, for a considerable part of the edible dry bean acreage in the United States, annual production rests upon a dangerously small germplasm base" (page 225). A similar statement is made about snap beans. Only recently have US breeders tried to broaden the genetic base of their breeding programs. While this will provide the means to achieve increased yield potential, change in architecture, (e.g., the use of NEP-2) etc., it will require long-term research efforts to fully utilize tropical germplasm, as the mechanisms and inheritance of adaptation are not well-understood. Increased attention to these matters is now needed to meet future needs. The difference in yield potential of small and large seeded types is a related problem which also needs to be resolved. The problems involved in adaptation research are the reason it has not been done more vigorously in the past. Existing new germplasm stored in the CIAT gene bank (which now comprises 35.000 accessions), or materials derived from it, nearly always perform very poorly in the US or Europe. Sixty percent

of CIAT's germplasm is photoperiod sensitive and not adapted to the US. Lack of understanding of the mechanisms and inheritance patterns of photoperiod and temperature adaptation greatly delay breeding efforts and hinder the addition of new variability to US breeding programs, thus limiting progress. CIAT was not established to support the US dry beans industry. Nevertheless, greater emphasis on research in this area could provide enormous benefits to the US bean industry. It will also be essential in improving the usefullness of CRSP projects, and in enhancing the return of existing or improved germplasm to tropical countries. The Cornell-Guatemala CRSP, for example, addressed these issues, by studying the photoperiod by temperature interaction on bean adaptation. However, it is too little and too early to benefit US breeders by offering methods to fully explore the entire wealth of tropical genetic variability in beans.

3. Digestibility and cooking time. Beans are a poor man's food. As income increases, consumption increases, especially of preferred grain type; but it declines again as income levels further increase. For example, in Brazil, for the high income quartile of the population, the expenditure elasticity for beans is estimated at - 0.28, but for the lowest income quartile at + 0.19 (CIAT, 1985). Wives participating in the job market, the time it takes to prepare beans, the "heaviness" of the meal, all contributed to the decline in bean consumption in the industrialized world. If the decline is to be prevented in the tropics and the human diet to be based on a wide variety of plant species, including beans, increased attention is needed to breeding for quality factors. Current attention to those factors in the CRSP is probably adequate. Some shift

of emphasis may be needed in order to learn more about genetic variability to better understand the magnitude of the environmental component and the inheritance of quality factors. Reduced emphasis may be given, at least initially, to the biochemical processes involved. Only when this information is available can quality factors be successful improved in breeding programs.

4. Disease Resistance. The emphasis on breeding for disease resistance should be redirected to some degree. Major tropical production problems, such as Bean Golden Mosaic Virus (BGMV) and Bean Yellow Mosaic Virus (BYMV), are very poorly understood and are far more important than some highly researched pathogens. Web blight, currently limiting the climate range over which beans can be grown in the tropics, is hardly researched at all. Universities have a clear advantage in providing the needed basic information on such diseases.

CONCLUSION

The emphasis in bean research in the past has stressed trying to reduce losses caused by diseases and pests. This strategy has, in general, not lead to yield increases. Failure may have been partly due to the narrow genetic base of most research programs. A change in research emphasis is, therefore, proposed.

Future research should be greatly increased in three main areas: breeding for increased yield potential; study of the photoperiod-temperature adaptation of beans, particularly at higher latitudes to widen available genetic variability; and, finally, to increase consumer acceptability of beans, especially urban consumers, by improving bean nutrition. I feel that attention to yield potential is especially required among researchers in the US and CIAT. However, the emphasis on breeding for disease resistance should continue at the national program level, where many scientists have been trained in this area. The CRSP and CIAT should narrow their disease resistance breeding programs and focus on major, unresolved problems, such as BGMV, web blight and, possibly, BYMV. New research emphasis should be funded by shifting resources: In the case of the CRSP, by concentrating more on basic research; and in the case of CIAT, by decentralizing research and supporting the genetic improvement through well-trained national programs.

Table 1. Results of black IBYAN trial of 1982 in 7 locations where yields were recorded above 3 t/ha and thus approach the genetic potential of the species, and average over all 36 locations where the trial was planted.

Variety/line	Yield 7 best locations	Yield over all 36 locations
Best CIAT bred line	3739	-
Jamapa	3412	1852
XAN 78	3298	1934
EMP 84	3256	1981
As above for IBYAN 1981 (4 and 22 sites respectively)		
Best CIAT bred line	4004	-
Jamapa	3634	1723
BAT 804	3522	1852
BAT 873	3477	1850

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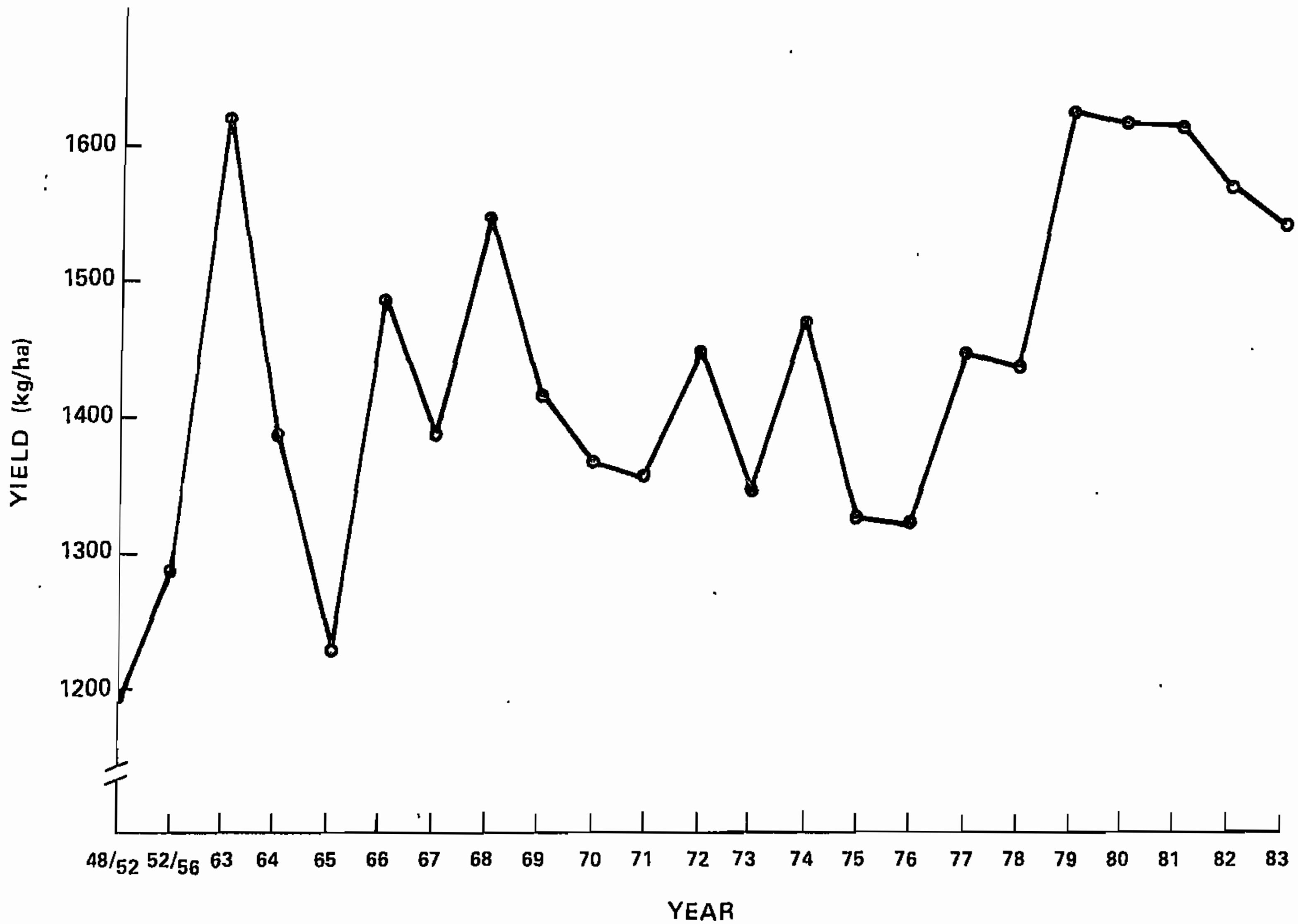

Fig. 1. Dry bean yield trends in the United States.