

Mungbeans: Taiwan, China

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Summary

In recent decades, cereal research and improved cultivation have led to more cereals and fewer pulses being grown. This has meant that people, particularly the poor, have lost a valuable source of protein. At the same time, monocropping of cereals has exhausted soils and made cereal cultivation less sustainable.

In 1971, the Asian Vegetable Research and Development Center (AVRDC) decided to do something about these threats, choosing the development of the mungbean as the focus of its project. The bean is indigenous to Taiwan, where it grows wild as a subsistence crop. As a result, AVRDC decided that it had a good chance of fitting the mungbean into modern, high-yielding grain systems throughout Asia.

The first step that AVRDC took was to remove or improve the traits of mungbean that made it an unpopular crop. Among the problems that researchers set out to resolve was that mungbean crops do not mature at once, so farmers have to harvest crops bit by bit, which is very time-consuming. In addition, the bean is low-yielding, slow to mature, susceptible to disease and dull-skinned.

Each season, AVRDC screened hundreds of thousands of plants, made crosses and distributed seeds to collaborating farmers who tested the seeds on their farms. The results of all this work were that potential yields more than doubled, crops started to mature at the same time, harvest time was reduced from 100 to 65 days, sensitivity to day-length (photoperiod) was minimized, and disease- and insect-resistant lines were developed.

Shorter harvest times meant that a mungbean crop can now be grown every year in rotation with a cereal. Research shows that wheat crops grown in such a rotation increase their yields by 20 to 30 percent. Mungbean therefore not only increases the availability of protein but contributes to increased sustainability and profitability of cereal crops.

In Pakistan, for instance, mungbean is now grown as a commercial crop, yielding US\$20 million annually in sales. Producers benefit from lower production costs, higher productivity and better prices for better quality beans while consumers continue to enjoy lower prices for lower-quality beans.

Future research and development plans include efforts to promote increased plant resistance to diseases and insects, even shorter harvest times (to allow cereal-cereal-mungbean rotations), mechanized cultivation practices, and development of tolerance to rain and humidity.

To achieve these goals, a mungbean network for South Asia has been established to carry out research backed up by tests and demonstrations on farmers' fields.

Background and Justification

In Asia, the green revolution concentrated exclusively on increasing cereal production and neglected all other food crops, including pulses, that had previously played an important part in cereal cropping systems. Far less land was given over to pulses, which were relegated to marginal areas where soils were less productive. Per capita pulse yields (and therefore soil protein availability) declined. Consequently, soils that supported one cereal crop after another started to lose their nutrients and deteriorate. Continuous cereal production also made it easier for diseases and insects to establish themselves on farmland, despite the increased use of fertilizers and pesticides. The ratio of farm outputs to inputs (total factor productivity) attained by cereal farmers declined dramatically.

Meanwhile, pulse prices increased 40 percent between 1982 and 1993 in India, and per capita consumption declined from 65.5 kg per year in 1963 to 37 kg in 1993. Protein deficiency among low-income groups also rose.

Mungbean (*Vigna radiata*) is an important pulse crop in south Asia where it supplies a substantial part of the protein consumed by the poor. It is high in protein, easy to digest and particularly nutritious

when combined with cereals because, while the cereals compensate for mungbean's low levels of sulfur amino acids, the beans compensate for cereals' shortage of lysine.

Resource-poor farmers like cultivating mungbean because it does not need a lot of water or other inputs and it helps to restore soil fertility through symbiotic nitrogen fixation. Worldwide annual cultivation of mungbean ranges from about 2.5 million tonnes to 5 million hectares.

Despite these advantages, original, unimproved South Asian mungbean varieties (known as *desi*) tend to be photoperiod-sensitive, low-yielding (potential yields of 700 kg per hectare from experiment stations drop to less than 300 kg per hectare in farmers' fields), asynchronous, and slow to mature (at 95 to 115 days). They produce small pods (5 to 6 cm) and small seeds (1,000 seeds weigh 20 to 25 g), which are dull green in appearance. They need long hours of daylight, so farmers have to postpone sowing. That, in turn, delays the sowing of subsequent cereal crop and makes it difficult to rotate crops. Unimproved varieties are susceptible to mungbean yellow mosaic virus (MYMV), cercospora leaf spot (CLS) and powdery mildew (PM).

All these characteristics made mungbean an unpopular crop. As a result, by the mid 1970s, it was being grown only on small patches of land outside the main cereal-based farming system.

In 1971, AVRDC decided that development of mungbean would be a good way of improving both human nutrition and the quality of farmland. The initial challenge was to overcome the bean's less positive characteristics. Koreana-born Hyo Guen Park, the project's first principal researcher, nicknamed this challenge SHE — standing for stability (resulting from disease resistance), high yields (to make the crop competitive) and early maturity (so that it could be fitted into intensive cereal-based systems).

The project has been a success. After a lengthy process of collecting and evaluating germplasm, breeding, and testing of new strains in various locations, new mungbean varieties are now uniformly and early-maturing, high-yielding disease-resistant and attractive. The seeds have brought benefits to producers and consumers alike — poor people enjoy a source of protein, cropping patterns are diversified, and soils are more fertile and productive.

AVRDC is not celebrating alone, however. National agricultural research systems (NARS) have collaborated in the project, scientists in the Philippines supplied high-yielding material and those in Pakistan developed the new strains' resistance to MYMV. After the project's early results of success, in 1983 the International Board for Plant Genetic Resources designated AVRDC as holder of the world mungbean base collection. Since then, the center has been the only international institute with a mandate to carry out mungbean research.

Description

AVRDC researchers challenged themselves to develop a mungbean that under optimum condition, would yield 4 tonnes per hectare; mature in 70 days (representing daily growth of some 57 kg per hectare); produce 20 pods per plant, 10 seeds per pod, and a seed weight of 60 g per 1,000 seeds; and have a plant intensity of 335,000 plants per hectare. The plant had to display a wide range of physical and growth characteristics, including a strong stem, root system and pods; the ability to photosynthesize efficiently; synchronized flowering and ripening; resistance to disease and pests; and tolerance to temperature and moisture. Many of these aims have since been achieved by lines that yield 2 tonnes per hectare in 55 to 70 days.

The research and development work is continuous and involves many countries sending material to the International Mungbean Nursery (IMB). To date, 5,615 mungbean accessions have been collected. Most have been evaluated in terms of their nutritional value, pest and disease resistance or tolerance, and growing characteristics. Some 6,460 crosses have been made and each season up to 300,000 plants are screened; so far more than 90,000 seed packets have been distributed in 127 countries.

The process worked like this: Plants whose germplasm have the desired characteristics are identified. These plants are crossed with high-yielding, uniform and early-maturing accessions from the Philippines. A variety of breeding methods are then combined and used on the crossed material to develop new breeding lines.

MYMV, the most serious threat to mungbean production in South Asia, is transmitted by the white fly. In 1992, AVRDC collaborated with South Asian NARS to establish a regional network to control the spread of this disease by screening mungbean populations for MYMV resistance and other

important characteristics. Pakistan's National Institute for Agriculture and Biology (NIAB) used mutation breeding to produce a large number of MYMV-resistant mungbean lines that they sent to AVRDC's Asian Regional Center (AVRDC-ARC) in Thailand in 1992. These lines were crossed with others and the crosses were sent back to NIAB to check that the resistance had been maintained.

After a year of tests, seeds were produced in Thailand for use in yield trials. A year later (1994), the result were lines that were MYMV- and CLS-resistant, high-yielding, large-seeded, and early- and uniformly-maturing. A total of 17 resistant lines originating in India, Pakistan and Sri Lanka were then returned to 20 other collaborating countries in South Asia and further afield.

To make it easier and quicker to introduce improved mungbean lines and evaluate and select the best lines for specific locations, AVRDC created a regional sub-network under the South Asian Vegetable Regional Network (SAVERNET) in 1997. During the following two years, seeds from 16 strains of mungbean were sent for trials in Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka. The lines that did best in each of these trials were then presented to local farmers through farm-based demonstrations.

Market research and analysis made it clear that, although Asian consumers accept mungbean as it is, demand could be increased by, for example, by introducing lower priced supplies and publishing recipes aimed at maximizing exploitation of the beans' nutritious ingredients and encouraging consumers to eat more mungbean. The following are the main improvements to come out of AVRDC and its collaborators' work with mungbean:

- Uniform maturity.
- Reduced time to harvest from 100 to 60 days.
- High yields of 2 tonnes per hectare compared with about 300 kg.
- Resistance to MYMV, CLS and other diseases.
- Increased seed weight at 70 g per 1,000 seeds.
- Larger, shinier seeds.
- Resistance to bruchids, a major pest during storage.
- Improved plant type with pods that are above the crop canopy.
- Increased demand for mungbean.
- 66 improved lines released in 22 countries.
- More than 1 million hectares planted worldwide with AVRDC's improved mungbean.

In Pakistan, one study shows that mungbean can contribute substantially to the national economy and that the benefits of the crop are shared by producers and consumers. In Pakistan alone, annual value added from improved mungbean amounts to an estimated US\$20 million.

Patenting and Commercialization

AVRDC has applied for no patents. Advanced mungbean lines are freely available to its NARS partners.

To date, AVRDC mungbean breeding lines account for 100 percent of Pakistan's 200,000 hectares of mungbean, 48 percent of Thailand's 421,000 hectares, and 60 percent of China's 1 million hectares, as well as substantial shares of Indonesia's, Myanmar's and the Philippines' total mungbean crops. Mungbean production is highest in countries that have efficient seed distribution systems. In Pakistan, for example, the public-sector Seed Supply Corporation of Punjab was instrumental in distributing improved seeds to farmers, and NIAB now supplements this by supplying seed. In Bangladesh, nongovernmental organizations produce and distribute seeds from AVRDC varieties.

Partnerships

AVRDC has made partnerships with the University of Minnesota to construct a genetic map of mungbean using RFLP markers; the University of Wisconsin to develop a DNA probe for MYMV; and the Australian Council for International Agriculture Research. Successes in China, Thailand and Pakistan have been extended to other countries through the SAVERNET network, the Cambodia, Laos and Vietnam network and the informal Asian Vegetable Network (AVNET) in southeast Asia.

Replicability

The research that led to mungbean's transformation from a traditional pulse crop to a modern vegetable commodity could be applied to other crops that are popular with consumers and that can be adapted to fit existing cropping patterns. What is needed is good collaboration with national partners. The approach and strategy that has been followed also can be adapted to smaller or larger scales to fit the available infrastructure, human resources and partnerships. AVRDC intends to apply some of the lessons and methods that it has learned through its work with mungbean to soybean research and development.

Lessons Learned

Researchers found that the following qualities and issues were particularly valuable to their work:

- Ability to see the potential of mungbean in resolving some serious agricultural problems.
- Clear, realistic goals that made the most of the existing situation and future developments.
- Determination to continue the work during the past 30 years despite staff changes.
- Interregional and interdisciplinary approach that benefits from the experience and knowledge of experts from other geographic and scientific areas.

AVRDC found that networks proved to be a good way of tackling the MYMV problem because network members can pool resources and expertise and cooperate with one another to help control and eradicate the disease.

Two international symposia in 1987 and 1994 helped to publicize AVRDC's findings to the wider scientific community. Such interaction led to greater interest in its work.

The central IMN nursery brings together developments and accessions made elsewhere and evaluates them to gather the best findings from many different countries and institutions.

Improved mungbean lines have not yet been adopted to cereal-cereal cropping systems but interviews with extensionists in Pakistan showed that it may be possible to insert a mungbean crop between a rice and a wheat crop. For now, this would be difficult because of competition for labour between wheat and rice harvesting and mungbean cultivation.

Research involving scientists from different disciplines should address this problem. Potential solutions include the development of mungbean varieties (or cereal crops) that mature more quickly and the mechanization of rice transplanting and wheat and mungbean harvesting. In some countries, the distribution of new lines has been hampered by inefficient extension systems. If a new line is to be adopted it must be obviously better than existing lines and provide immediate gains to its users. Potential benefits to all producing and consuming participants must be taken into account and there must be incentives for everyone involved.

To ensure producers have adequate markets, it may be necessary to increase consumer awareness of mungbean and its advantages. This can be done through information campaigns and development of new recipes to suit local conditions. Popularity also will be increased by such features as improved appearance, good cooking qualities and higher nutritional values.

Impact

In 1994, AVRDC's staff socio-economist analysed the impact of improved mungbean in Pakistan and found that the center's NM92 cultivar had virtually replaced the low-yielding *desi* variety. Compared with *desi*, the new line has 55 percent higher yields, generates returns that are four times higher, reduces the cost per unit of production by about 25 percent, and improves the benefit-to-cost ratio by about 70 percent. Similar results were found in Thailand.

These productivity gains have led to mungbean accounting for a far larger share of Pakistan's total pulse production, up from 3 percent in the 1980s to 11 percent in 1994. Per capita annual consumption of mungbeans grew by 30 percent over the same period, while consumption of other pulses stagnated or declined.

Mungbean has now become a commercial crop that improves land productivity and reduces the inputs (nitrogen and labour) needed by other crops such as wheat, while increasing the outputs. Moreover, wheat in a wheat-mungbean rotation costs 26 percent less to produce than it does in rotations with other crops. Wheat production, as a result, rose rapidly in marginal wheat-producing areas. Between 1986 and

1993, for example, it increased by 4.4 percent per year in these areas compared with 3 percent for the country as a whole.

Effective innovations improved the standards of living of mungbean growers by increasing their incomes and benefited consumers by supplying better quality beans at lower prices. Roughly 38 percent of the total benefits of improved mungbean went to consumers and 62 percent to producers. This contrasts with cereal research which generates far more benefits for consumers than producers.

Future Plans

AVRDC will continue its efforts to improve mungbean yields. Different strains of MYMC, CLS and PM from different geographical areas, for example, are being identified and ways of including mungbean in cereal-cereal cropping systems are being explored to improve the sustainability of these systems. This means reducing the time it takes mungbean to mature. Before this can be accomplished, researchers must find out why the bean's early growth is so slow. Advances in mechanization, such as development of a mungbean harvester, would help to solve conflicting demands for labour in a cereal-mungbean-cereal system, and there is a need to find mungbean lines that can withstand high rainfall and flooding without rupturing their pods.

AVRDC is also investigating ways of combining mungbean with other foods to make the most of its nutritional potential. For example, eating tomatoes with mungbean makes more of the bean's iron content available to the people who eat it. In this way, mungbean could help curb iron deficiency problems in developing countries.

AVRDC also plans to test the potential for growing mungbean in other regions, including Africa, where its low input and management requirements, particularly for water, and its high productivity make it an attractive option. High iron and protein contents make the crop valuable to countries where these nutrients are deficient. The center will continue to share its improved technologies and expertise with existing partners throughout south Asia.

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