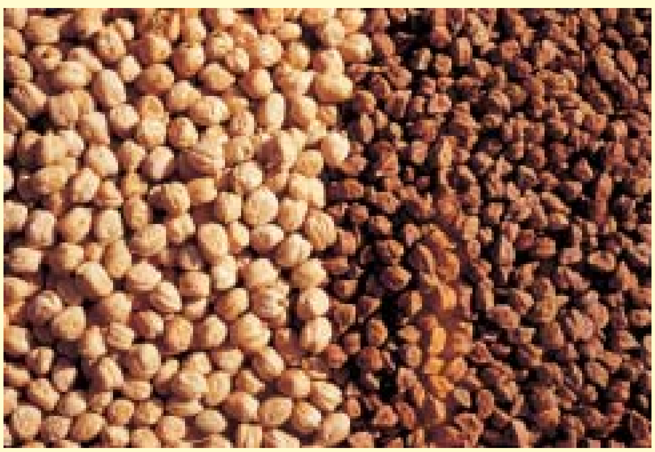
Changing Lives in Marginal Environments

ICRISAT and ICARDA: a Winning Partnership in Chickpea Research

Chickpea (*Cicer arietinum*) is the most important leguminous food grain in the diets of people in South and West Asia and northern Africa. It is grown on over 11 million hectares worldwide, and annual production averages over 8 million tons. Although chickpea is traditionally grown in the developing world, new breeding advances have made it possible to cultivate it in Canada, the USA and Australia.

There are two types of chickpea. *Desi* is traditionally grown in warmer climates and predominates in South Asia and East Africa. *Kabuli* is a large-seeded type suited to the more temperate climates of West Asia.



Kabuli (left), which takes its name from Kabul, Afghanistan, is suited to the cooler climates. Desi (right), which means ëlocalí in Hindi, is typically grown in tropical areas.

Sub-Saharan Africa and South Asia have the world's highest concentrations of poverty: over 500 million desperately poor people. Chickpea is the main source of dietary protein for many of them. Meat, because it is too expensive, or, in some communities, restricted by culture and religion, is often unavailable. Chickpea is also a key income earner for millions of smallholder farmers in South Asia and parts of Africa, especially Ethiopia and Tanzania.

ICRISAT and ICARDA share a mandate for the improvement of chickpea. While ICRISAT focuses on *desi* types in the tropical latitudes of South Asia and

Scientists from Central Asia and the Caucasus (CAC) and Eritrea examine improved kabuli lines developed through gene pyramiding at ICARDAís headquarters at Aleppo, Syria.

Sub-Saharan Africa, ICARDA takes the lead in *kabuli* types in the arid temperate zones of Central and West Asia and North Africa (CWANA).

The joint research conducted with partners around the world has generated enormous benefits. Over 100 improved varieties have been released in 27 countries, and chickpea area and productivity have increased dramatically in the tropics, and large new production areas have been created.

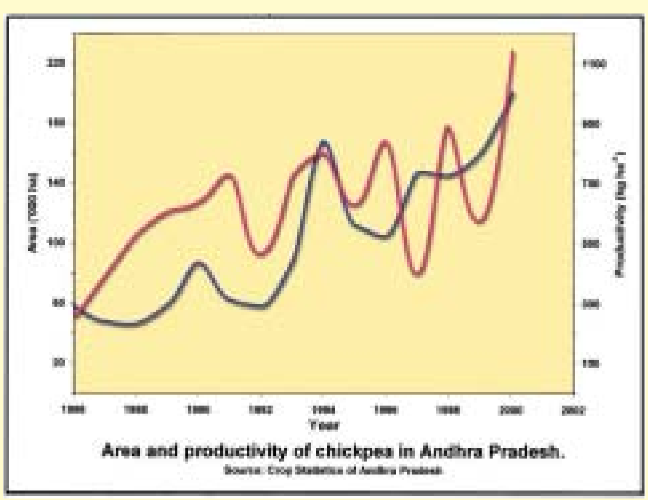
1. Impact on farmers and poor people

Chickpea research at ICRISAT and ICARDA has dealt with five major stresses, which together cause annual losses of over $2 billion. Drought, which alone accounts for half this amount, is by far the most important. *Helicoverpa* pod borer ($500 million), fusarium wilt ($250 million), ascochyta blight ($250

Swetha is a godsend to farmers for two reasons: it is the first kabuli variety to achieve widespread popularity in the Indian tropics, and it is the shortest-duration variety in the world.

million) and botrytis gray mold ($100 million) account for the rest.

India. Because chickpea is generally cultivated on residual moisture under rainfed conditions, one of ICRISAT's most significant achievements has been the development of short-duration varieties that escape terminal drought. ICCV 2 or *Swetha*, the first *kabuli* variety ever released in peninsular India, is the world's shortest-duration variety, maturing in only 85-90 days. It also resists the devastating fusarium wilt disease. *Swetha* was instrumental in extending chickpea cultivation into tropical latitudes, and has led to additional advances such as the bolder-seeded *kabuli* cultivar KAK 2, which, because of its higher premium market price, is spreading quickly throughout the region.



Area and productivity of chickpea in Andhra Pradesh.
Source: Crop Statistics of Andhra Pradesh

Significantly, chickpea cultivation has expanded into tropical Andhra Pradesh state, where in 1986 only 60,000 ha were sown to the crop. By 2000, the chickpea area had expanded to 200,000 ha. The trend is certain to continue. Dr A Satyanarayana, Director of Extension of the Archarya NG Ranga Agricultural University, the premier agricultural college in the state, believes that farmers will sow 400,000 ha to chickpea during *rabi*, the postrainy season, in 2002. But the number of hectares is only part of the story. Productivity has also increased enormously – from 260 kg ha^{-1} in 1986 to 1000 kg ha^{-1} today. The significance of this increase is worth underscoring. Andhra Pradesh, long considered outside the chickpea area, now boasts productivity *25% higher than the national average*. A study conducted in three districts indicated that improved chickpea varieties occupy one third of the total chickpea area in those districts, and that the farmers who adopted these varieties obtained an additional net income of $55 ha^{-1} over the traditional variety. Taken together, increases in both hectarage and productivity in the state mean a *twenty-fold* increase in production since 1986.

Improved varieties have also become popular in the states of Maharashtra, Gujarat, Karnataka and Madhya Pradesh. A study conducted in five districts of Maharashtra revealed that improved chickpeas occupy nearly 40% of the total area, and that adoption has given poor farmers an additional net income of $80 ha^{-1}.

Myanmar. In Myanmar, where chickpea was grown on over 164,000 ha in 2001, has become a major exporter. Taking note of the country's two major constraints, a short growing season and fusarium wilt, breeders developed the first wilt-resistant variety *Schwe Kyehmon* (ICC 5003 x F 378), and followed this success with *kabuli* variety ICCV 2. Not only were

Ketema Daba, a researcher at Debre Zeit, with a crop of Shasho (ICCV 93512), a kabuli type popular with Ethiopian farmers.

the two major constraints to chickpea production removed, but the crop became a *cash earner*.

Ethiopia. Ethiopia is another major chickpea producer, accounting for over half of Africa's entire chickpea area. Several new varieties, both *desi* and *kabuli* types, have been introduced and developed by ICRISAT and ICARDA and released by the national program. Some of them are extremely popular: ICC 5003 x F378 (*Mariye*), ICCL 82104 (*Worku Golden*), ICCL 82106 (*Akaki*), ICCV 93512 (*Shasho*) and FLIP 89-84C (*Arerti*). The spread of *Mariye*, which has rapidly become the predominant cultivar in Bichena province, provides an excellent example of farmer-driven development. The cultivar moved from farm to farm until the entire province was saturated.

In 2001, chickpea was sown on 212,000 ha in Ethiopia, and commercial cultivation is growing every year. Ethiopia exports chickpeas to Pakistan, India, Dubai and Afghanistan, and domestic demand far outstrips supply. In markets, chickpea sells for three times the price of wheat or maize. Farmers have urged their NARS to develop and release varieties suited to the heavy black clay soils that typify much of Ethiopia's highland areas. ICARDA/ICRISAT work has focused on these areas, combining variety development with crop and land management technologies that allow farmers to maximize benefits from the new varieties.

Bangladesh. In the Barind Tracts of northwestern Bangladesh, where agriculture in the postrainy season has been impossible for uncounted generations, a mini-revolution is taking place. In the early nineties, Canadian donors, teaming up with ICRISAT and the Bangladesh Agricultural Research Institute (BARI), sought a leguminous crop that could survive in the rice fallows on receding soil moisture during the dry season. The researchers determined that chickpea was the most suitable crop if the seeds were sown immediately after the rice harvest, especially if they were primed by soaking in water overnight. Because the value of chickpea is equivalent to that of rainy-season rice, cultivation of the crop has had immediate economic impact at the village level. The UK's Department for International Development (DFID) is currently undertaking an impact assessment of chickpea adoption in the Barind, and preliminary results indicate that the crop has changed thousands of lives. The economic returns to chickpea cultivation means that many children, notably girls, are attending school for the first time.

A recent survey indicates that during the 2001/02 season, ICRISAT/BARI varieties occupied 85% of the

Nowhere has chickpea made greater impact than in Bangladesh. Just 10 years ago the crop was sown by only a handful of farmers. Today, thanks to superlative extension work by BARI, various NGOs and focused donor support, notably from Canada and DFID, chickpea is cultivated by tens of thousands of Asiaís poorest farmers.

An added bonus

The people of the Barind have found that the top twig of the chickpea plant is good to eat. Known as shak*, the twigs are important both nutritionally as a green vegetable and as a source of cash. Significantly, whether it is eaten or sold,* shak *is controlled exclusively by women, making this novel use of chickpea a source of empowerment.*

Below: a farmer plucks shak *for her family.*

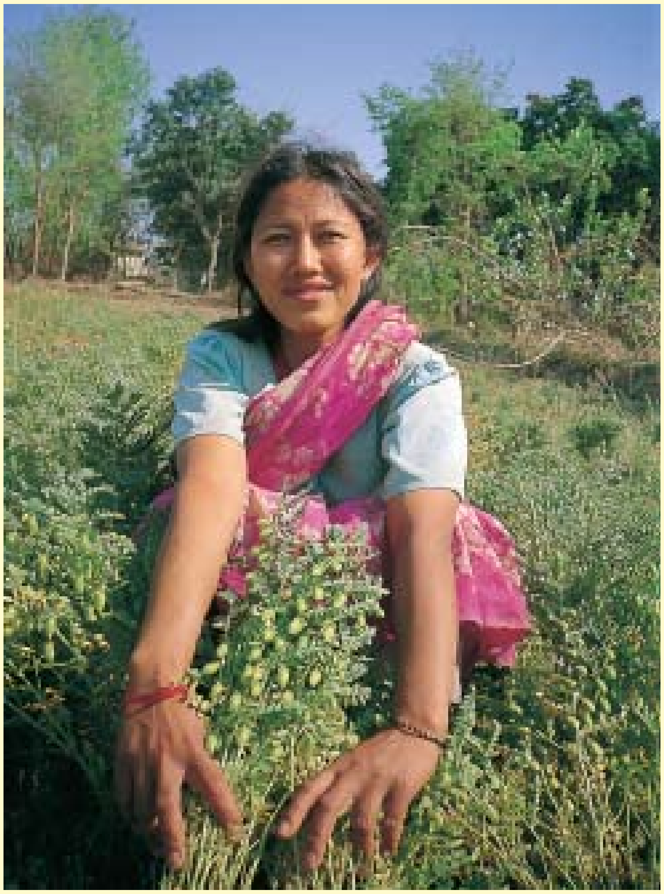
Right: close-up of the shak *twig.*

They say a picture is worth a thousand words. The farmer who tills this land obviously has access to precious irrigation water, which traditionally was used to grow postrainy-season rice, as shown on the left. Yet he has also chosen to grow chickpea, which requires no irrigation at all, in the adjacent plot. This is a clear indication of farmer preference for a legume crop that provides his family with both food and income.

chickpea area. On average, these improved varieties gave 55% higher yield than local varieties. Moreover, chickpea gave *three times* higher returns than other postrainy-season crops. It is not surprising that adoption by farmers is increasing every season. Since 1999, a span of only 3 years, the area under chickpea in the Barind has doubled.

The potential of this initiative of sowing chickpeas in rice fallows is enormous. Over an area of about 14 million hectares within the Indo-Gangetic Plain across three countries – Bangladesh, India and Nepal – in soils that have lain fallow for centuries after the rice harvest, a crop can now be grown where nothing grew before.

Nepal. In the Terai of Nepal, the main constraint to chickpea production is a two-headed monster – a disease, botrytis gray mold, and an insect, *Helicoverpa*



Chickpea, discarded by Nepalese farmers exasperated by disease and insect pests only four years ago, has made an astonishingly quick comeback due to the new resistant varieties developed by ICRISAT and disseminated by their Government.

pod borer. These two biotic stresses wreaked so much havoc on chickpea in Nepal in the late nineties that production was not even quantifiable, and farmers simply gave up trying. But when new integrated disease and pest management technologies developed by the CGIAR/NARS partnership were introduced to farmers' fields, the crop came back with a vengeance. In one district, from a total of 110 farmers applying these technologies in 1999, no less than 7000 now practice them in 14 districts. After the 1998/99 season, when chickpea was sown in 110 farmers' fields using the new technologies, there was no sign of the disease. Adoption quickly spread, and the 1999/2000 season saw a *fivefold* increase in adoption.

2. Impact on sustainable production systems

Winter planting. In Iran, where chickpea is traditionally sown in the spring, ICARDA scientists and their NARS partners tested a new technology called *entzari*, or winter planting. In *entzari*, chickpea is sown in autumn before the winter sets in, and the seeds lie dormant in the soil until spring. Ascochyta blight resistance made this technology possible. They then germinate and establish long before the fields are ready for cultivation. Farmers get *75% more yield* than with their traditional spring-planted crop. No small wonder that they are rapidly adopting this practice. Within the last three years, 7000 hectares of chickpea were pre-winter planted.

An important breakthrough has also been made with early-maturing, blight-resistant *Myles* in Canada.

Winter sowing vs traditional spring sowing of kabuli chickpea. ICARDA scientists have shown that yield advantages of up to 60% can be achieved by sowing in winter instead of spring in Mediterranean-type environments.

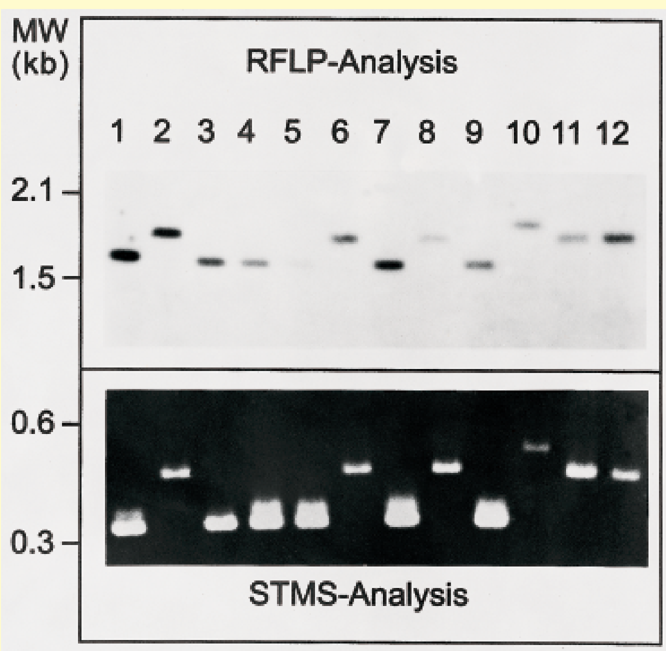
IDM and IPM. Researchers at ICARDA, in collaboration with the NARS of Syria and Morocco, introduced integrated disease management (IDM) to crops plagued by both ascochyta blight and weeds. In Syria, four control components led to significant yield increases: use of tolerant cultivars adapted to early sowing, seed dressing with fungicides to prevent seed-borne disease, application of a single foliar spray of a fungicide at seedling or early vegetative growth stages, and delayed sowing until January for lower disease impact.

In Morocco, major gains over traditional spring-sown chickpea resulted from winter sowing and early weed control. Seed yield varied from 766 to 2440 kg ha^{-1} for winter planting and from 160 to 1250 kg ha^{-1} for conventional spring planting. Advancing the sowing date from spring to winter using adapted chickpea varieties with the IDM package increased yields substantially.

Investigating the economics of integrated pest management (IPM), scientists found that the cost of crop protection using nuclear polyhedrosis virus (NPV) saved about $100 per hectare while providing the same degree of yield protection as costly and hazardous use of insecticides. A cost-effective, village-level NPV production technology has been transferred effectively in seven villages of Andhra Pradesh. Similar technical assistance has been provided to several state governments in India, as well as in Bangladesh and Nepal. According to IFAD, this work has resulted in a 6-100% reduction in chemical pesticide usage in farmers' fields in these countries (IFAD Pulses IPM Progress Report 1999-2000). This is a work in progress, and the results are exciting to watch as they unfold.

3. Scientific innovation

Early and super-early lines. By pioneering the development of extra-early (85-90 days) varieties of chickpea, such as ICCV 2 and ICCC 37, ICRISAT has been able to extend chickpea cultivation into tropical environments and rice fallows for the first time. The



Restriction fragment length polymorphism (RFLP) and STMS analyses of an F_1 population of Ascochyta rabiei *in lanes 3-12, and the individual parents in lanes 1 and 2. Both RFLP and STMS allow one to trace the F_1 bands back to the parents, and detect the increased allele size in one of the progeny.*

Regeneration of shoots from callus of the embryo rescued from interspecific hybridization of chickpea (inset). Young researchers from several developing countries receive training in biotechnology at ICARDA. Here, trainees from India, China, Colombia, Lebanon and Algeria learn DNA-marker techniques.

institute's breeders went even further and developed *super*-early chickpea lines ICCV 96029 and ICCV 96030, which mature in only 75-80 days (normally, chickpea takes 120 days to mature in South India). These lines are now under widespread use in crossing programs all over the world. Moreover, super-early chickpea can be promoted as a cash crop between early-maturing rice and wheat, the most prevalent cropping system in northwestern India.

Genomics. An excellent example of upstream research started with the development of the specific sequence tagged microsatellite site (STMS) marker system by ICARDA scientists, in collaboration with Guenter Kahl's team at Goethe University in Germany, in 1995. With a marker mapping system for chickpea finally a reality, new horizons became possible. Washington State University and ICRISAT are now using the ICARDA/Goethe STMS system to map important traits, creating the world's first useful molecular marker-based linkage map for the cultivated species of chickpea. A total of 166 markers were mapped to 17 linkage groups. And in collaboration with the University of Frankfurt and Washington State University, ICARDA constructed an integrated molecular map of the interspecific chickpea genome containing 350 markers. This is a giant step forward.

Transgenics. There's more. ICRISAT has successfully produced transgenic chickpea plants for resistance to *Helicoverpa* pod borer using genes derived from the bacterium *Bacillus thuringiensis* (*Bt*) and soybeans

ICARDA has successfully transferred genes for resistance to nematodes from wild to cultivated chickpea.

(soybean trypsin inhibitor). While the molecular characterization and insect bioassays are ongoing, the effectiveness of alternative sources of insecticidal genes, including those derived from *Bt* are currently being developed and evaluated at ICRISAT in collaboration with CIRAD scientists.

Scientists at the University of Hannover, after establishing that the agrobacterium transformation into embryo-axes is the most suitable system for genetic transformation of chickpea, moved its team to ICARDA's research headquarters at Aleppo to jointly develop a regeneration and transformation system for chickpea.

New genes. New genes have been identified for earliness *(efl-1)*; fusarium wilt *(h1, h2, h3)*; flower and stem colors *(p, b, c)*; nodes to first flower *(nfl1)*; early growth vigor *(evg1 and 2)*; and double pods *(s),* as genetic markers on the chickpea genome.

Wild species. A number of wild *Cicer* species have high degrees of resistance to wilt, soil-borne fungi, gray mold, blight, cyst nematode, leaf miner, and bruchid beetle. They also tolerate cold and drought. ICRISAT collaborates closely with ICARDA to transfer the genes of these wild species to cultivated chickpea. For example, when crossed with chickpea, *C. reticulatum* provided important traits like cyst nematode resistance, cold tolerance and high biomass – all of which were successfully transferred to chickpea at ICARDA. Most importantly, these singular achievements have been accompanied by training programs and national capacity building, ensuring that developing-world agricultural research systems are not left behind.

Screening techniques for stresses. ICRISAT and ICARDA have developed reliable and cost-effective screening techniques for resistance to fusarium wilt, ascochyta blight, botrytis gray mold *and Helicoverpa* pod borer, and tolerance for drought and cold. These techniques have been transferred to NARS scientists and are being used widely in germplasm screening and resistance breeding.

Kenyan farmers hail the champ. Chickpea is winning support everywhere.

4. Partnerships

Chickpea research at both ICRISAT and ICARDA is based on partnerships. The partners include national agricultural research and extension systems, advanced research institutes, other CGIAR Centers, universities, NGOs and farmer groups. The research agenda and priorities are determined by national research programs and regional organizations.

NARS. ICRISAT has helped several national agricultural research systems (NARS) establish research programs on chickpea, or expand their chickpea programs to address specific constraints like ascochyta blight. Collaboration covers germplasm exchange, variety development, plant protection and farmer-participatory technology evaluation. Partners include Afghanistan, Algeria, Australia, Bangladesh, Canada, Central Asia and the Caucasus (CAC), China, Cyprus, Ethiopia, Germany, India, Iran, Italy, Kenya, Lebanon, Malawi, Mexico, Morocco, Myanmar, Nepal, Pakistan, Spain, Sudan, Syria, Tanzania, Tunisia, Turkey, Uganda, USA and Zambia.

Universities and Advanced Research Institutes. Collaboration covers different areas. The University of Frankfurt, the University of Saskatchewan and Washington State University are helping to construct a molecular map of the chickpea genome. The University of Hannover is helping to develop a regeneration and transformation system for chickpea. Collaborative studies with the Scottish Crops Research Institute focus on transferring a resistance gene from kiwi fruit to chickpea, and on characterization and detection of chickpea viruses. The Max Plank Institute, Germany, is collaborating on studies on the mechanisms of pod borer resistance. Other institutes from Australia, USA, Thailand and France work on biological nitrogen fixation research. Studies on photoperiod-temperature interactions were carried out jointly with the University of Reading, UK.

Often, these partnerships expand and become formalized as networks, making technology testing, sharing, and germplasm exchange more effective. Examples include regional networks for the WANA and CAC regions (coordinated by ICARDA). Research collaboration and technology exchange in Asia are coordinated through the Cereals and Legumes Asia Network (CLAN) hosted by ICRISAT and involving 13 countries. The ICARDA Legume International Testing Network now includes over 50 countries. CIMMYT, IRRI and other members of the Rice Wheat Consortium of the Indo-Gangetic Plain also feature importantly in these partnerships.

Conclusion

Partnerships are necessarily a delicate balance. In the corporate world, each member of a partnership must ensure the scales do not tip in the other's direction. But the partnership between ICRISAT and ICARDA is different because both are tipping the scales in the same direction – towards the poor farmers of the semi-arid and arid areas of Asia and Africa.

Success in agricultural research for the marginal regions of the world is often painfully slow. But the dedicated researchers of ICRISAT and ICARDA who committed themselves to the achievement of results 30 years ago never faltered in their mission. Success may have been a long time coming, but it has come, and it has come in spades.

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Photo: Sarwat Hussain, CGIAR

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