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A Success Story of

Fruitful Partnership between the Bangladesh Agricultural Research Institute and International Center for Agricultural Research in the Dry Areas

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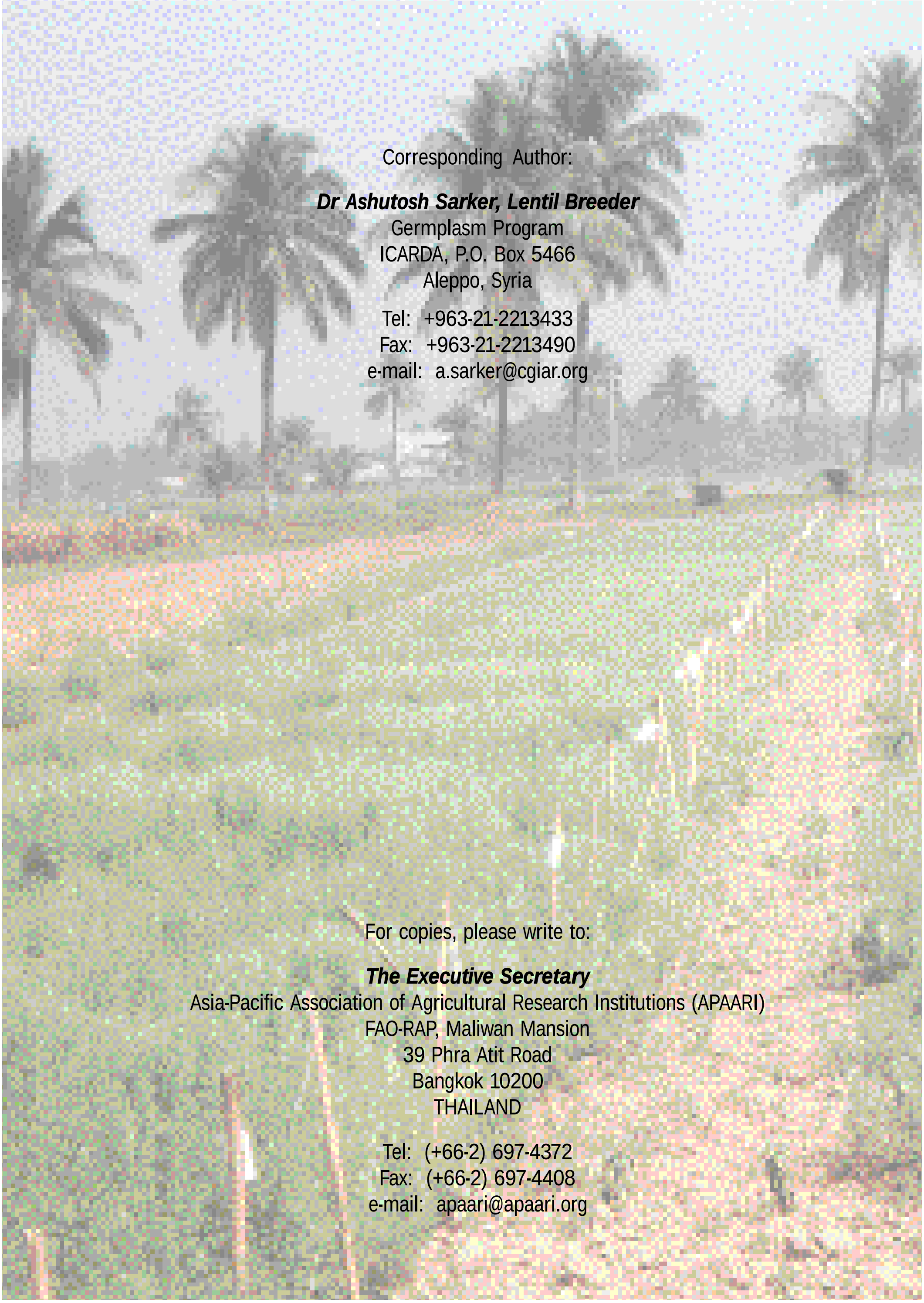

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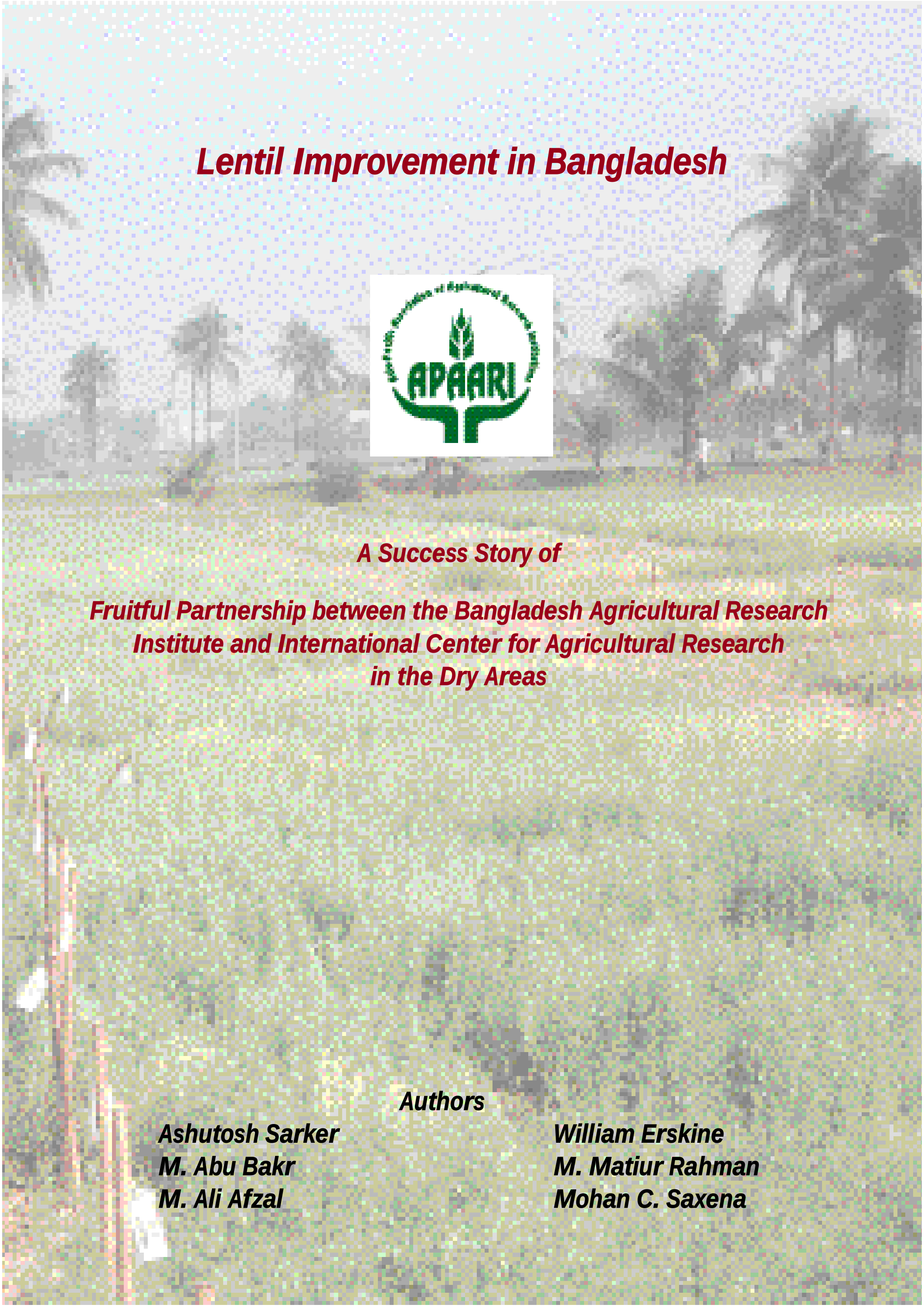

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FOREWORD

The Asia-Pacific Association of Agricultural Research Institutions (APAARI) is an active regional forum, which acts as a catalyst to promote and strengthen agricultural research and development in the Asia-Pacific region. It has been involved in facilitating collaboration and cooperation in the region through various institutional, regional and global linkages. The Association has been well recognized for its dedicated activities by various international bodies including the CGIAR, and FAO of the United Nations. It also publishes newsletters, and proceedings and recommendations of various meetings/symposia on agricultural development and research held in the region. Among others, it has published more than a dozen success stories of its member institutions in various fields of agricultural technology development, adoption and impact. The forum also plays an active role in agricultural research priority setting exercises, where farmers' problems are addressed.

Lentil is a staple pulse in many developing countries, including Bangladesh. It is number one pulse with respect to consumption, among a dozen of pulses grown in the country. It is a rich source of dietary protein and micronutrients for majority the people in the country, and is eaten as a soup called dal with rice. Lentil is also important in crop diversification in the cropping systems of Bangladesh. The Pulses Research Center of the Bangladesh Agricultural Research Institute (BARI) has been engaged in lentil research since late-seventies.

Since its inception, BARI has established strong linkages with the International Center for Agricultural Research in the Dry Areas (ICARDA), based in Aleppo, Syria. With its world mandate for lentil *improvement, ICARDA has put a major emphasis on lentil improvement in South Asia, where Bangladesh is strong partner. Through ICARDA's decentralized breeding strategy for short-season environments of South Asia, Bangladesh has developed disease-resistant, improved lentil varieties, which are now being cultivated by farmers. I am glad to know that the farmers of Bangladesh are benefiting from improved lentil technologies, based on improved varieties, agronomic management, and cropping systems. I compliment the scientists of BARI and ICARDA for their contributions to improving the welfare of resource-poor farmers of Bangladesh*

Lentil research in Bangladesh, however, did not end with technology development. A Government-funded Technology Transfer Pilot Project was put in place to ensure that new technology reaches the farmers. It gives me great pleasure to learn that the leaders of the South Asian national programs have shown a keen interest in including lentil under the Cereals and Legume Asia Network (CLAN) operating from ICRISAT, India. With APAARI's proposition, and ICARDA's endorsement, lentil has now been included in CLAN portfolio. This means that its research and development activities will get a new momentum in South Asia. The success story, "Lentil Improvement in Bangladesh" is an example of a successful partnership between national agricultural research system, ICARDA and other international centers.

I am confident that this publication will be of great use to the national programs engaged in lentil research and development in the region aimed at increasing lentil production under their respective agro-climatic conditions. I thank the authors for taking the initiative to develop this publication based on their research in lentil improvement.

R.S. Paroda
Executive Secretary

I. INTRODUCTION

Among the major food crops in the Asia-Pacific region, particularly South, East and Southeast Asia, pulses as nutritionally rich food, play an important role in improving the diet of the people. The countries in the region grow a dozen of summer and winter pulses to meet the dietary requirements, particularly for the poorer section of the society, to whom animal protein is less accessible. APAARI plays the role of facilitator to promote and coordinate agricultural research and development in the region through research networking. It has been supportive to the Cereals and Legumes Asia Network (CLAN), administered from ICRISAT, India. Lentil being an important pulse crop of Asia-Pacific region (which covers about 53% and produces 49% of world's lentil (Table 1), and recently became a CLAN mandate crop, APAARI has been instrumental in dissemination of information, material exchange and sharing of resources among the members of CLAN.

In Bangladesh, production of major food crops – rice, wheat, pulses and oilseeds – does not meet the present requirements of

Table 1: Production scenario of lentil in Asia-Pacific region

Country	***Area ('000 ha)***	***Production ('000 t)***	***Productivity (kg/ha)***
Australia	128	207	1,617
Bangladesh	154	116	752
China	90	132	1,467
India	1,390	950	684
Nepal	182	148	813
Pakistan	46	29	638
World	***3,765***	***3,208***	***852***
% of world	53	49	–

Source: FAO production year book, 2004.

country's population of about 135 million. The gap is widening both in quantity and quality. Agricultural scientists are faced with the complex and urgent task of bringing the "population – food supply" equation into rational balance. Rice and wheat have been the focus of concerted government effort in research and development. Similar attention was long overdue for the pulse crops, commonly known as poor man's meat.

Pulses are vital components in diversification of Bangladesh's predominantly rice-based cropping system. Lentil is the second most important pulse crop in terms of area (154,000 ha) and production (116,000 t), but ranks the highest in consumer preference and total consumption (BBS, 2002). Lentil seed is a rich source of protein and several essential micronutrients (Fe, Zn, β-carotene) (Bhatty, 1988). Only red cotyledon type is used as food in Bangladesh, where it is boiled into soup-like dhal and eaten with flat bread (roti) or rice. Khichuri is another popular dish, which is made from a mixture of split lentil seed and pounded wheat or rice. Lentil straw is valued animal feed.

Domestic pulse production satisfies less than half of the country's needs. The rest, some 140,000 tonnes, is imported at a cost of about US$ 32.2 million per annum. Lentil, purchased mostly from Australia, Nepal, Turkey and Canada, accounts for US$17.6 million (MOA, 2002). The resulting high prices have led to widespread protein malnutrition, especially among vulnerable groups, such as rural children and the aged. Bangladeshis consume about 12.0 g of pulses per capita per day, far below the 45 g per day recommended by FAO/WHO (Islam and Ali, 2002). Meat production, including fish, has declined consistently in recent years, so animal sources of protein are also priced beyond the reach of the poor.

In an effort to become self-sufficient in pulse production, and reduce the drain on foreign exchange, the government of Bangladesh, policy makers, scientists and the extension department have launched

Figure 1: A rural mother is feeding rice and lentil dal to her children

pulse improvement and development programs in the country. The research component is the responsibility of the Pulses Research Center of the Bangladesh Agricultural Research Institute (BARI), located at Ishurdi, an intensive lentil-growing area. The Center has enjoyed strong collaboration with the International Center for Agricultural Research in the Dry Areas (ICARDA), Syria, since the early 1980s when Bangladesh stepped up its research into lentil improvement.

II. HISTORICAL PERSPECTIVES

Lentil research was initiated in the early 1950s, but was confined to the collection and evaluation of local germplasm (Gowda and Kaul, 1982). A few lines were tested over different locations during the early 1960s, but research virtually stopped because the germplasm was not *properly maintained. To halt steady decline in pulse production and attain self-sufficiency, an intensive research effort was launched at BARI in 1979 under a research grant project of the International Development Research Center (IDRC), Canada. In the mid-1980s the Pulses Improvement Program of BARI transformed into the Pulses Research Center (PRC) with its headquarters at Ishurdi, Pabna, a representative pulse-growing areas in Bangladesh. The Center established its five regional testing stations; Joydebpur, Jessore, Barisal, Hathhajari and Rajshahi. The Center formed a multi-disciplinary team of researchers comprising of breeders, agronomists, pathologists, entomologist, soil scientist, post-harvest technologist, nutritionist, and socio-economist. In late-eighties, the Center became involved in national crop diversification program funded by Canadian International Development Agency (CIDA), Canada. The Center also received a support grant particularly for lentil improvement research from the Australian Center for International Agricultural Research (ACIAR), Australia, which was implemented by ICARDA.*

BARI has been working to improve lentil through conventional breeding approaches. Strategies were adopted to develop high-yielding lentil varieties suitable to the cropping system of short season environment quickly, through introduction or germplasm, particularly from ICARDA. Top priority was given to collection and evaluation of local and exotic lentil lines. At the same time, work on improved production packages, including pest and disease management, agronomic and cultural management also received due emphasis.

III. MAJOR PRODUCTION CONSTRAINTS

The main genetic and cultural factors contributing to the low productivity of lentil in Bangladesh include:

1. ***Low yield potential of local cultivars****, owing to less branching, low podding intensity, and very small seed size.*

2. ***Local cultivars' susceptibility to major diseases****, such as lentil rust and Stemphylium blight. Collar rot is becoming a serious threat at seedling stage, especially in saturated soil.*
3. ***Poor response to high inputs of fertilizer and irrigation****, as genetic erosion has occurred in most of the pulses due to continuous cultivation in marginal, poor soils.*
4. ***Yield instability due to biotic and abiotic stresses*** *discourages farmers from growing lentil. In the last few years, heavy rainfall during the flowering stage has caused considerable yield loss. Development of improved, stress resistant varieties is essential.*
5. ***Delayed sowing****, due mostly to delays in rice harvest, reduces lentil yield by shortening the period for vegetative growth, in the already short winter season of 100-110 days.*
6. ***Farmers lack motivation*** *to put effort into lentil production. They think that lentil can be grown without care, so they ignore the recommended production package and focus their attention, and resources, on rice and wheat instead.*

Figure 2a & 2b: A local cultivar susceptible to diseases

IV. Significant Achievements in Lentil Improvement

Germplasm Collection and Evaluation

Augmenting Germplasm Diversity of Indigenous and Exotic Collections

In the last two decades, PRC have collected and evaluated about 504 indigenous and more than 2000 exotic germplasm accessions. The first local collection mission was conducted in 1981 in collaboration with the University of Southampton, UK, where collection was done from the lentil growing northwestern region of Bangladesh (greater Kustia, Jessore, Faridpur, Khulna, Pabna districts). A total of 193 accessions were collected from fields, village markets, and from farmer's stocks. The second expedition was organized under CIDA grant in 1993 to collect indigenous germplasm from Rajshahi, Bogra, Dinajpur and Rangpur districts and 83 accessions were collected. In 1994, under the same grant, lentil germplasm was collected from saline-prone southern part of Bangladesh (Barisal, Noakhali, Chittaging, and Comilla districts, and a total of 166 accessions were added with the earlier collection. The Genetic Resources Unit of ICARDA made another expedition in 1997 to collect lentil germplasm from Tangail, Manikgunj, Jamalpur and Gazipur districts and 62 accessions were collected.

Sources of exotic germplasm are from ICARDA. Under the Material Transfer Agreement (MTA), ICARDA supplies early maturing germplasm of various origins. These materials are sent through ICARDA's Legume International Nursery Network, as special dispatches, which include germplasm, breeding lines and segregating populations. Among stress nurseries, Lentil International Rust Nurseries (LIRN) and Lentil International Drought Nursery (LIDN) are sent to Bangladesh. The Elite nurseries consist of early maturing *genotypes. Segregating populations are specifically made for Bangladesh using its elite landraces and parents of diverse origin. In early days, ICARDA-supplied germplasm of West Asian origin did not flower at all in mild winter and short-season environments of Bangladesh. To address various stresses of lentil, genotypes with resistance to rust, Stemphylium blight, wilt, and drought were supplied. It is estimated that a total of about 2065 germplasm and breeding lines have been supplied to BARI since 1979.*

Figure 3: Evaluation of exotic germplasm at the experimental farm of the Pulses Research Center, Ishurdi, Pabna

Field Characterization/Evaluation of Germplasm

In general, field evaluation of indigenous germplasm showed very narrow variability with respect to flowering, maturity (<110 days), plant height, seed size (all small, 1.4-1.6 g/100 seeds), test color and seed shape, seed yield and other yield contributing traits. The landraces are susceptible to both rust and Stemphylium blight diseases. On the *contrary the exotic germplasm have wide variability, which are being used by national researchers. Some of the highly promising lines with key important traits are given in Table 2. As the agro-ecological and cropping systems conditions of South Asia are more or less similar, the information provided here will benefit other national programs.*

Table 2: Key traits possessed by some exotic elite germplasm received from ICARDA

Traits	Local	Accessions
Maturity (105-120 days)	105-110 d	ILL 4605, ILL 8090, ILL 8010, ILL 6002, ILL 7723, ILL 4404, ILL 4402, ILL 4684, ILL 5073, ILL 5093, ILL 5094, ILL 5106
100 Seed Weight (> 2.5 g)	1.4-1.6 g	ILL 4605, ILL 7723, ILL 590, ILL 7723, ILL 6447, ILL 6819, ILL 6829, ILL 7163, ILL 7537, ILL 7543, ILL 7716, ILL 5143, ILL 6419, ILL 6420, ILL 6367, ILL 6419, ILL 7656
Resistant to rust & Stemphylium blight diseases	Susceptible	ILL 4605, ILL 8008, ILL 590, ILL 7979, ILL 7980, ILL 7981, ILL 6004, ILL 6024, ILL 6467, ILL 7657, ILL 6818

Varietal Improvement and Development

Development of short duration lentil varieties with stable and higher yields, resistant/tolerant to rust and Stemphylium blight, and suitable for inter or mixed cropping are the key research objectives of PRC. Through national and international efforts, PRC released four improved varieties (Table 3).

Table 3: Lentil varieties released by the Pulses Research Center, Bangladesh

Variety	Year of release	Origin	Maturity (days)	Seed size (g/100 seeds)	Yield (t/ha)
Uthfala (Barimasur-1)	1991	Local selection	110	1.6	1.3-1.5
Barimasur-2	1993	ICARDA	110	1.5	1.8
Barimasur-3	1996	Local cross	115	2.5	2.0
Barimasur-4	1996	ICARDA	116	1.7	2.3

Uthfala *is an early maturing, small-seeded, semi-dwarf type, with determinate growth pattern, and good podding intensity. It was selected from a landrace, Pabna, and released in 1991 with national accession number BLL 79694 (Sarker et al., 1992). It has an average yield of 1.3-1.5 t/ha, and is less susceptible to rust and Stemphylium blight than the local cultivars. Stem pigmentation is absent at the seedling stage, but is light green at the late-vegetative stage. Leaves are dark green with slight pubescence. Leaf size is medium with a dark green, short petiole and rachis that form no tendrils. Its flower is white. Seed color is ash and testa is dotted. The seeds are smooth seed surface with red cotyledon. The average 100-seed weight is 1.6 g. Its recovery percentage (splitted/dehulled quantity from whole seed) is 74%. The variety requires 16 minutes to cook, which is liked by the consumers. Its seed contains 27.8% protein. The variety is suitable for sole cultivation in all lentil-growing areas in Bangladesh.*

Barimasur-2 *emanated from ICARDA-supplied genetic material and was released in Bangladesh in 1993 for its high yield and wide adaptability with a high level of resistance to rust (Sarker et al., 1999a). It was developed through single plant selection from a cross ILL 4353 (India) × ILL 353 (Mexico) made at ICARDA. The variety out-yielded the check, Uthfala, by 20%, with an average yield of 1.8 t/ha. Barimasur-2 is a semi-erect and medium stature cultivar with mean plant height of 40 cm. Leaves are pubescent and grey-green, with narrow terminal leaflets and ending in a short tendril. Stems are light green, flowers white, seed coat light gray without pattern, and cotyledon bright orange. It has a 100-seed weight of 1.5 g. The cultivar matures in 110 days, which is similar to Uthfala and traditional landraces. The major achievement is that it is the first rust resistant lentil variety that provides stability in yield. Seed of Barimasur-2 retains 89% kernel content after dehulling, but actual recovery after splitting by traditional manual method is 76%, compared with 73% for local cultivars. It requires 15 minutes of cooking time, with 52% solid* *dispersion. Its seed protein content is 28.3%. The variety is performing well in Natore, Rajshahi and Pabna districts in both as sole and inter-cropping with sugarcane.*

Barimasur-3 *was released in Bangladesh in 1996 for its stable and higher yield, medium seed size, and resistance to rust. It was developed through a national hybridization program from a cross between BLL 7966 (Indian) and Pabna Local (landrace), made at PRC (Sarker et al., 1999c). The variety produces a mean seed yield of 2.0 t/ha, is medium in stature (42-44 cm), and semi-erect with more basal primary branches. The leaves are dark green with broad leaflets (without tendrils), flowers are white, and pods and leaves turn to straw color, while the stem remains green at maturity. It has a 100-seed weight of 2.5 g, which is much bigger than the locals. The farmers like the variety for to its bigger seed size. Seeds of Barimasur-3 has 76% recovery with traditional manual dehulling method. It takes 21 minutes to cook and shows 52% solid dispersion. Dehulled seed contains 26.9% protein and 47% carbohydrate. Adoption of Barimasur-3 has been seen in Rajbari, Faridpur and Kustia areas, mostly as sole and mixed cropping with mustard and wheat.*

Barimasur-4 *was released in Bangladesh in 1996 for its stable and high yield and its resistance to rust and Stemphylium blight (Sarker et al., 1999b). It was developed from the cross ILL 5888 × ILL 5782 made at ICARDA in Syria specifically for Bangladesh. The female parent (Uthfala) was an improved lentil variety developed through pure-line selection from a landrace in Bangladesh. Barimasur-4 produced an average mean seed yield of 2,300 kg/ha compared to 1,800 kg/ha for Barimasur-2. It has a 28% yield advantage over Barimasur-2 and a 53% advantage over the standard check, Uthfala. Due to its wide adaptability, the cultivar is recommended for all lentil-growing areas in Bangladesh.*

Barimasur-4 is an erect cultivar of medium stature (40-42 cm) with long fruiting branches. The stems have anthocyanin pigmentation, the leaves are light green with narrow leaflets and rudimentary tendril. The flower is bluish-purple, and the pods, leaves and stemsturn a light-straw color at maturity. Most leaflets are shed at 100% pod maturity. The seed coat is reddish-grey, dotted, and cotyledon is light orange. It has a 100-seed weight of about 1.7 g. The variety matures in 116 days, approximately one week later than landraces; however, this does not hamper the existing cropping pattern. Barimasur-4 has high levels of resistance to lentil rust and Stemphylium blight diseases. It is the only variety grown in Bangladesh that has combined resistance against these two major diseases. Seeds of the cultivar have 89% kernel content, but produce 78% head dahl. It takes about 17 minutes to cook and shows solid dispersion of 54%. It contains 28.5% protein and 48% carbohydrate. The most important agronomic advantage of this cultivar is that, having an erect growth habit, more plants can be accommodated per unit area. It is a potential cultivar for intercropping with sugarcane, and mixed cropping with mustard. The cultivar is popular all over lentil-growing areas of Bangladesh except Rajbari and Faridpur areas.

Figure 4: A farmer in Chawadanga district is growing Barimasur-4 lentil variety

Crop Management

a. **Optimum planting time:** *Time of planting is a key factor in achieving higher yield in lentil, as it affects the environmental conditions to which the crop is exposed at various stages of phenological development. In Bangladesh, lentil is grown after the rainy season on conserved soil moisture. When grown after upland Aus paddy or jute, lentil can be sown in late October. When following harvest of transplanted rice, lentil is sown in November to mid December. Winter in Bangladesh is very short (100-110 days) and mild. Farmers are advised to sow lentil by the first week of November. Delayed sowing hampers growth, resulting in poor yield (Khan and Miah, 1986).*

b. **Seed rate:** *Plant stand density of 250 plants/m^2 was found to produce higher yield in lentil in Bangladesh (Rahman and Miah, 1989). For optimum plant stand density, seed rates of 35-40 kg/ha for Uthfala, Barimasur-2 and Barimasur-4, and 40-45 kg/ha for Barimasur-3 have been recommended and are being practiced by farmers.*

c. **Relay cropping:** *Relay cropping entails sowing a second crop before harvesting the first crop. This gives plants more time for vegetative growth, makes use of residual moisture, and reduces cost of production by dispensing with tillage for the second crop. Lentil relayed after transplanted rice is uncommon in Bangladesh, although farmers are used to relay planting grasspea. Experience from Nepal encouraged researchers at BARI to find optimum sowing time and seed rate for lentil relay cropping. The technology is suitable in the medium lowlands, where lentil cultivation is almost impossible after rice.*

Barimasur-2 and Barimasur-4 preformed well under relay cropping (Table 4). A seed rate of 40-45 kg/ha was found to produce optimum plant population and higher yield. Lentil seeds should be broadcast 15-20 days before rice harvest in saturated soil. Farmers are adopting the practice.

Table 4: Lentil yield under relay and normal planting

Variety	Production system	Yield (kg/ha)
Barimasur-2	Relay (without tillage)	1,100-1,200
Barimasur-4	Relay (without tillage)	1,300-1,500
Local cultivar	With tillage	780

Figure 5a: Relay cropping of Barimasur-4 lentil variety in transplanted rice field in experimental field at Ishurdi

Figure 5b: A farmer, Md. Alef Biswas (on the right), of Bagh Hashra village expects to harvest more than 2.0 t/ha from his relay crop with Barimasur-4 lentil variety

d. **Seed Priming:** *Seed priming is an old technology, but many farmers are unaware of its benefit and do not practice it. (Moreover, the farmers are not aware of the 'safe limit' of seed priming.) It is common to find patchy plant stands the result of poor and uneven germination when lentil is sown after several tillage operations. During land preparation, moisture is depleted through evaporation, which reduces germination. Seed priming, whereby seed is soaked in water, usually overnight, before being surface dried and then sown, improves plant stands, enhances early vigor, and results in earlier maturity, reduced disease, and increased yield. Research with improved varieties has shown yield increase of 29-38% from priming (Table 5). The technique is being disseminated through extension messages, and farmers are benefiting.*

Table 5: Effect of seed priming in lentil varieties

Priming level	Variety	Yield (kg/ha)	Increase (%)
Non-primed	Barimasur-2	1,567	–
8 hours seed primed	Barimasur-2	2,155	37.5
Non-primed	Barimasur-4	1,842	–
8 hours seed primed	Barimasur-4	2,380	29.2

e. **Mixed and intercropping:** *More than half of lentil in Bangladesh is grown mixed and intercropped with other winter crops, such as wheat, mustard, linseed, barley, and sugarcane. This helps farmers avoid the risk of total crop failure and increases total productivity per unit area. For example, the most compatible and economically profitable seeding ratios were 2:1 or 1:2, wheat: lentil (Ahmed et al., 1987). The highest yield advantage was achieved in mixed cropping of mustard: lentil with a seed ratio of 3:1.*

Intercropping of lentil with sugarcane is most widespread. Barimasur-4, being an erect type, is suited to intercropping with sugarcane – more plants can be accommodated per unit area and canopy geometry of the crops is compatible for light interception. Most farmers in Natore, Kustia, Jessore districts have adopted Barimasur-4 as an intercrop with sugarcane, and are enjoying increased income as a result.

Figure 6: Lentil variety Barimasur-3 in-inter cropping with sugarcane (left) and Barimasur-2 lentil variety is in mixed-cropping with Brassica.

f. Management of diseases: *Of the 16 diseases of lentil reported in Bangladesh, rust caused by Uromyces viciae-fabae (Pers.) Schroet. (Pucciniaceae, Uredinales) and Stemphylium blight caused by Stemphylium botryosum Wallr. (Dematiaceae, Hyphales) are the most devastating (Bakr, 1993). They occur frequently in all lentil-growing areas in the country, to the point where farmers were abandoning the crop. High humidity, cloudy weather, and average temperatures of 20-22°C promote rust, which generally occurs in early February in the northwest and in late January in the south. In epidemic years, complete crop failure has been observed due to Stemphylium blight. High humidity, coupled with ambient night temperature around 8°C and mean day temperature above 22°C, promotes blight.*

Host-plant resistance has been adopted as a key strategy to combat these diseases. The resistance sources now in the hands of Bangladeshi researchers were obtained from external sources, mostly ICARDA. The decentralized breeding approach followed by ICARDA has resulted in introgression of resistance genes of West Asian origin. As mentioned in earlier sections, three of the four varieties have good levels of resistance and gave yield stability. Of the improved varieties, Barimasur-4 has combined resistance against rust and blight, and has become popular due to its greater stability.

Recently, new sources of combined resistance have been selected from targeted segregating populations supplied by ICARDA. Rust can be avoided to a great extent by planting early maturing cultivars. Disease control by applying fungicides has been effective. Dithane M-45 (0.2%) or wettable sulfur or 0.25% Ferbam have been found to be effective in controlling rust. Rovral 50 WP has been shown to control Stemphylium blight with three sprays at an interval of 7 days starting from the onset of the disease.

Figure 7: Rust and Stemphylium blight resistant lines (left) and resistant line, Barimasur-4 (right)

V. LENTIL CULTIVATIONS IN DIFFERENT CROPPING PATTERNS

In Bangladesh, lentil is traditionally grown during the dry winter months (rabi season) on residual soil moisture under rainfed conditions. Lentil faces serious competition with wheat, boro rice, oilseeds, potatoes and other profitable winter crops, particularly where irrigation is available. As a result, the crop has been pushed to marginal and sub-marginal lands.

Rice is grown extensively throughout the year in Bangladesh, so all the major cropping patterns are rice-based, but vary widely depending on agro-ecological zone. The major lentil growing districts are greater Faridpur, Jessore, Kustia, Pabna, and Rajshahi (Figure 2). Lentil is grown mainly as a mono-crop in Bangladesh, but mixed cropping and intercropping with wheat, mustard, linseed, sugarcane, and other crops is practiced in some areas (Mia and Rahman, 1993). In eastern Bangladesh, relay cropping in rice fields is practiced on a very small scale. The major lentil-oriented cropping patterns are:

Broadcast Aus paddy/Jute-fallow-lentil: Areas of Kustia, Rajbari, Magura, Jessore districts in medium-high topography lands with sandy-loam soil. Sometimes, lentil is grown as mixed crop with mustard, wheat, linseed. Lentil varieties, Barimasur-2, Barimasur-3 and Barimasur-4 are being cultivated in these areas.

Jute-fallow-Lentil: In medium-low topography areas of Faridpur, Pabna, Natore, Kustia where Corchorus capsularis jute is grown in water stagnated condition in rainy season. Lentil is grown after receding floodwater in clay-loam soil. Barimasur-2 is better adapted.

Aus paddy/Jute-fallow-lentil + mustard: Growing lentils in mixed cropping with mustard is an age-old profitable practice in Bangladesh.

Broad-cast Aman rice-Lentil: *Lentil is grown in low-lying areas of Faridpur, Kustia, Rajbari, Pabna, Natore districts in heavy clay soil. Barimasur-4 improved variety is better adapted in these areas.*

Transplanted Aman rice-Lentil-Jute/upland rice: *In medium topography areas of Jessore, Chawadanga, Magura, Meherpur, Kustia, Rajshahi districts in sandy-loam soil.*

Sugarcane+lentil inter-cropping: *In vast areas of Jessore, Chawadanga, Meherpur, Kustia, Jhinaidah, Natore, Pabna, Rajbari, Magura districts, lentil is grown in sandy-loam to clay-loam soils. Barimasur-4 is the most popular variety in these areas. However, Barimasur-3 is better adopted in Rajbari and Faridpur; and Barimasur-2 has gained popularity in Natore and Rajshahi districts.*

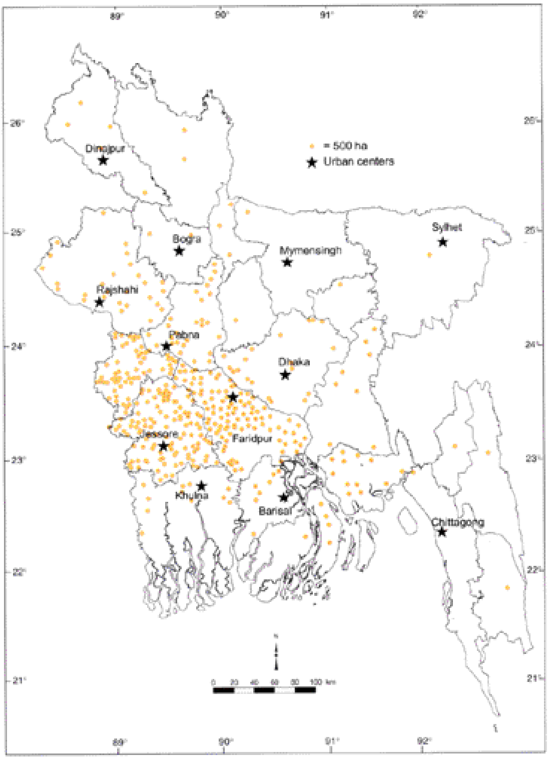

Figure 8: Lentil growing areas in Bangladesh

VI. COLLABORATION WITH ICARDA AND OTHER INTERNATIONAL ORGANIZATIONS/REGIONAL NETWORKS

ICARDA is an international, not-for-profit scientific research and training center funded through the Consultative Group on International Agricultural Research (CGIAR). It has a world mandate for lentil improvement in the developing countries. Informal collaboration between BARI and ICARDA started in the early 1980s. As stated earlier, ICARDA has been collaborating with the PRC of BARI in supplying improved genetic materials, segregating populations, sources of quality traits and resistance to various stresses. The major constraint to lentil improvement in Bangladesh was the lack of genetic variability in traits of importance in local germplasm (Sarker et al., 1991). Having established that the landraces were susceptible to diseases, introductions were made from India. Because they were late maturing, they could not fit into the cropping systems in the short-season environments of Bangladesh, and they were susceptible to diseases. Diversity was needed from outside the region.

ICARDA became the prime source of exotic lentil germplasm and breeding lines for Bangladesh. To date, more than 2000 germplasm accessions and breeding lines, with specific valuable traits, including biotic and abiotic stress resistance, have been supplied to BARI. The Genetic Resources Division of BARI conserves these materials under long-term (-20°C), medium-term (4°C) storages. About 45 accessions including improved varieties, introduced lines, locally developed breeding lines are being used as working collection.

Only limited success was achieved, however, in selecting or developing promising genotypes through direct introduction (Sarker et al., 1991). The breeding strategy was revised to include hybridization, and ICARDA was requested to make crosses for Bangladesh using improved landraces (Rahman and Sarker, 1993). ICARDA had

Figure 9: BARI and ICARDA scientists with extensionists and farmers in a lentil field with improved variety in Magura

germplasm with resistance to Stemphylium blight and rust diseases, the major production constraints of lentil in Bangladesh.

Around that time, ICARDA changed its international lentil breeding program to better serve the needs of national programs and take into account their increased capability (Erskine et al., 1998). A decentralized-breeding approach was launched that involved ICARDA developing segregating populations using parents from national programs, and incorporating blight and rust resistance. Targeted segregating populations were shipped to Bangladesh and selections were made under local agroclimatic conditions. The result was rust resistant cultivar Barimasur-2 (Sarker et al., 1999a), followed two years later by Barimasur-4, which yielded 2.3 t/ha, compared to 1.3 t/ha for the improved local variety Uthfala (Sarker et al., 1999b).

Figure 10a. Precursor of Barimasur-4 (disease free) vs. local with complete crop failure. Research done at Pulse Research Center, Ishurdi, Bangladesh

Figure 10b. Barimasur-4 at the Pulse Research Center, Ishurdi

As stated earlier, rejuvenation of pulses research activities started in late-seventies with financial support from IDRC, Canada. Most of the preliminary activities, including acquisition of germplasm and manpower development were taken into consideration, and a full-fledged Pulses Research Center was established. Its continuation was supported by CIDA, and improved varieties and production and protection technologies were developed. During this period, mostly in-country training of junior staff, extensionists and farmers were carried out. The FAO provided technical support to BARI, Bangladesh by providing consultant to the PRC. With the cessation of CIDA grant, PRC was assisted by external funding from ACIAR for a period of three years. Research focused on varietal development, on-farm seed *priming, relay cropping, mixed and intercropping, and disease management.*

In "Lentil Improvement in South Asia" conference held in 2002 in Katmandu, Nepal a proposal for the development of a "South Asian Network for Lentil Improvement (SANLI)" was proposed (Sarker et al., 2002). All participating members from South Asia, APAARI and CLAN supported the proposal. As bilateral cooperation has been very weak, it was felt that a regional network would be beneficial for all the collaborating countries. It was decided that exchange of germplasm, improved technologies, human resource development, traveling workshops will be carried out among four South Asian countries (Bangladesh, India, Nepal and Pakistan) under APAARI umbrella, and would be executed by CLAN and ICARDA. APAARI's catalytic role to promote the exchange of scientific and technical know-how, assist in strengthening research capability, developing linkages among national, regional and international research organizations was lauded by the national scientists. Its proactive role in publication and information disseminations would be of great help to the national programs. In a recent meeting (November 2003) at ICRISAT, APAARI's proposal to include lentil under CLAN mandate was appreciated by the national program scientists of South Asia, which was finally endorsed.

VII. HUMAN RESOURCES DEVELOPMENT

Nineteen Bangladeshi researchers have participated in short and long term training courses and study visits organized by ICARDA to learn about crop improvement, crop production and management, plant protection, and statistical design and analysis of experiments (Table 6). The PRC has now developed its own hybridization program making use of crossing techniques learned at ICARDA.

Table 6: Training and visits of Bangladesh scientists in lentil improvement implemented by ICARDA

Year	Training	Visit	Venue
1978 & 1979	4-month (3)	–	ICARDA, Syria
1983	3-month (1)	–	ICARDA, Syria
1984	4-month (1)	–	ICARDA, Syria
1992	–	10 days (1)	ICARDA, Syria
1994	–	8 days (1)	ICARDA, Syria
1995	2-month (2)	–	ICARDA, Syria
1997	3-month (1)	–	ICARDA, Syria
1998	2-month (1)	–	ICARDA, Syria
1999	2-month (1)	–	ICARDA, Syria
2000	3-month (1) 1.5-month (1)	– – 10 days (1)	VIDA, Australia ICARDA, Syria ICARDA, Syria
2001	1-month (2)	–	PAU, India
2002	1-month (1)	–	ICARDA, Syria
2003	2-month (1)	–	ICARDA, Syria

(Figures in parenthesis are number of persons)
PAU-Punjab Agricultural University
VIDA-Victorian Institute for Dryland Agriculture

VIII. FACTORS UNDERLYING SUCCESS

a. Technology transfer: *Technology demonstration and dissemination was the key to success in improving lentil production and productivity in Bangladesh. Along with disease resistant varieties, appropriate production technologies, including optimum planting time, seed rate, profitable seeding ratio in inter and mixed cropping, weed control, seed priming, relay cropping, diseases management, etc., have been developed, recommended, and delivered to the farmers through extension services (Afzal et al., 1999). To popularize the new technologies, the Government of Bangladesh has launched* *a technology transfer mission called the Lentil, Blackgram and Mungbean Development Pilot Project (LBMDPP) from its own resources in the 1996/97 cropping season. For the last seven years the project has laid tremendous emphasis in the following areas:*

- *Foundation seed production of improved lentil varieties*
- *Large-block demonstrations involving 10 farmers per location*
- *Assessment of varietal performance through farmer participation*
- *Free distribution of seeds, fertilizer and other inputs to the farmers*
- *Farmer training (pre-sowing and post-harvest)*
- *Organizing mobile workshops for researchers, extensionists and NGO staff*
- *Extension-Research-NGO training workshops*
- *Organizing field days at crop maturity*
- *Awards to the best farmers and extension workers*
- *Procurement of seed from farmers for the next year's distribution*
- *Publicizing improved technologies through national media, technical bulletins, leaflets, booklets and posters*

Foundation seed production was mainly done by PRC and Bangladesh Agricultural Development Corporation (BADC). Total amount of breeder seed and foundation seed production is shown in Table 9. Under the project activities, pre- and post harvest training of farmers, research and extension staff was carried out at BARI headquarters, Joydebpur and at PRC regional stations (Table 7). A total of 13,017 participants took part in various training programs.

Table 7: Training activities on improved lentil technology

Training programs	No. of Training	Participants
Pre-sowing farmers training on lentil	60	2,890
Post harvest farmers training on lentil	55	2,850
Extension agents and research staff training	31	1,490
Scientist and extension officers training and workshop	17	650
Bifertilizer production and utilization	2	112
Field days	49	5,025
Total	***214***	***13,017***

Publicity of improved varieties and technologies were given due importance, and regarded as a key component of technology dissemination and adoption. Various form of publicity tools were developed and used (Table 8).

Table 8: Publication and publicity activities on improved lentil technology

Publicity means	No. Published	No. Distributed
Booklet	***10,000***	***4,500***
Lentil Cultivation in Bangladesh	10,000	4,500
Leaflet/Folder	***8,000***	***60,000***
Barimasur-1	20,000	15,000
Barimasur-2	20,000	15,000
Barimasur-3	20,000	15,000
Barimasur-4	20,000	15,000
Annual Report (1997-98)	500	350
Annual Report (1998-99)	500	200
Annual Report (1999-2000)	500	150
Colorful Poster	10,000	3,500
Radio Advertisement	21 Days	

Large-scale farmer's field demonstrations have been the main vehicle of technology advertisement and dissemination. Improved technologies were demonstrated against farmer's traditional technologies to compare and convince farmers towards improved technologies. During the last six years, a total of 1,166 demonstrations were conducted involving 12,440 farmers following a mosaic pattern in intensive lentil-growing zones of Bangladesh (Table 9).

Table 9: Technology demonstration in farmers' fields

Year	No. of Demonstrations	Area (ha)	No. of farmers involved
1997-98	32	43	320
1998-99	160	210	1,680
1999-00	200	265	2,090
2000-01	220	290	2,200
2001-02	300	400	3,050
2002-03	254	340	3,060
Total	**1,166**	**1,548**	**12,400**

b. Institutional support and linkages: *The Project has brought together research and development components. It was felt that dependence entirely on formal agricultural extension services might result in slow or no transfer of technology. The project has brought together the concerned research and development partners led by BARI. Five other organizations, namely Bangladesh Institute of Nuclear Agriculture (BINA), Directorate of Agricultural Extension (DAE), Bangabandhu Shaikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh Agricultural Development Corporation (BADC) and local NGOs (World Vision, Ghoroni) became partners in the technology transfer mission with major executing responsibility placed on BARI, which supplies labour and logistics for technology dissemination. In foundation seed production, mainly BARI and BADC took active part, while in technology dissemination all institutions except BADC did demonstrations. Human resources* *development and farmers' empowerment were accomplished by BARI, DAE and BINA.*

c. Participatory approach in technology dissemination: *The project follows a participatory approach in technology dissemination involving all partners, including farmers, in each and every step of planning, execution, and evaluation. The Project's stepwise activities have included: organizing a broad-based policy planning workshop with the key representatives of all partner organizations, NGOs and farmer representatives; and regional workshops to develop annual work plans. The grass root extension workers, the extension block supervisors, scientific assistants (SA) and participating farmers were trained on the technology package and implementation methodology. Technology packages were demonstrated in farmers' fields following cluster demonstrations (1.25 ha per cluster). Improved seed and fertilizers required for each demonstration were supplied from the project. Inputs were given directly to the participating farmers. DAE block supervisors and project SA initially supervised the setting up of the demonstrations. Activities are monitored by project administrators at least twice per cropping season. Participants from all partner organizations monitor and evaluate the demonstrations during traveling workshops and they identify constraints related to technology transfer and adoption. The group also selects the farmers deserving of awards.*

d. Motivational activities: *Creating farmer awareness and interest in new technologies is a critical step in technology adoption. In this regard, a number of steps were undertaken. Formal training on the technologies was given to the researchers and extension officers, field level extension workers, research assistants, and progressive farmers from each of the blocks selected for cluster demonstration. Information about the technologies was supplied in the form of attractive leaflets, booklets, and posters in simple local language. Demonstrations were set near public passages to fields to expose neighbouring farmers the technologies. Field days were organized to demonstrate the technology.*

Figure 11a: Farmers in a field day

Figure 11b: Demonstration of improved variety

Figure 11c: Seed distribution of improved varieties to the farmers

Figure 11d: A farmer Md. Abdul Sattar from Ishurdi is receiving "Best Farmer" award from the Minister of Agriculture for producing 2.7 t/ha lentil seeds by cultivating improved lentil varieties

e. Seed production and distribution: *Availability of seed of improved varieties is another critical factor in variety dissemination. The project initiated a massive seed production program with various organizations involved in the project (Table 10). Of them, BADC and contract growers are the major players in seed supply. Apart from the formal seed distribution system, informal farmer-to-farmer seed diffusion takes place at the village level. Sometimes, registered seed dealers also sell seeds in village markets. There is good demand for seeds of the improved lentil varieties.*

Table 10: Seed production and distribution, 1997-98 to 2002-03

Varieties	Breeder Seed (kg)		Certified Seed (kg)	
	Production	Distribution	Production	Distribution
Barimasur-1	700	620	10,500	9,000
Barimasur-2	800	750	10,000	9,000
Barimasur-3	900	800	10,500	9,000
Barimasur-4	1,100	950	13,000	12,000
Total	***3,500***	***3,120***	***44,000***	***39,000***

IX. ADOPTION AND IMPACT OF IMPROVED TECHNOLOGIES

a. Adoption of technology: *The technology transfer activities under the Pilot Project have been underway for the past seven years in major lentil growing areas, comprising Madaripur, Rajbari, Faridpur, Magura, Jhinaidah, Chawadanga, Norail, Jessore, Kustia, Pabna, Meherpur, Natore and Comilla districts. To monitor the progress of technology transfer and adoption, impact assessment studies are being conducted by the socio-economists and related scientists at PRC. A most recent study was undertaken after the 2002-03 crop harvest.*

Among four improved varieties, Uthfala became highly susceptible to rust and Stemphylium blight and farmers have virtually abandoned the variety. Among the others, Barimasur-4 has been highly adopted because of its consistently stable performance and higher yield. The farmers of Faridpur and Rajbari prefer Barimasur-3 due to its disease tolerance and larger seed size. Adoption of improved varieties was observed more among block farmers than non-block farmers. Among the improved varieties, Barimasur-3 and Barimasur-4 are most popular. It has been estimated that the local landraces have been replaced by the improved varieties on about 60,000 ha, of which about 39,000 hais under Barimasur-4. Improved varieties out-yield local varieties in each of six years studied (Figures 12 & 13) by an average of about 60%.

Adoption of improved agronomic practices has been seen mostly among block farmers. Line sowing, appropriate seed rate, optimum-planting time, etc., were followed as recommended. The technique of seed priming is spreading fast among the farmers, where lentil is being grown after tillage operations. Relay cropping is gaining popularity mainly in non-traditional areas.

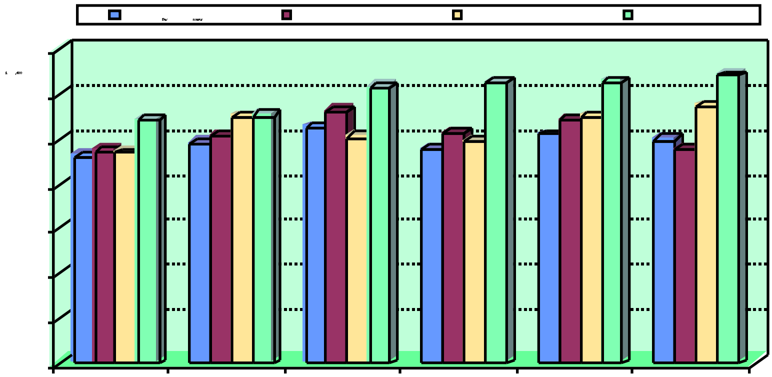

Figure 12: Seed yield (kg/ha) of improved varieties cultivated by the farmers

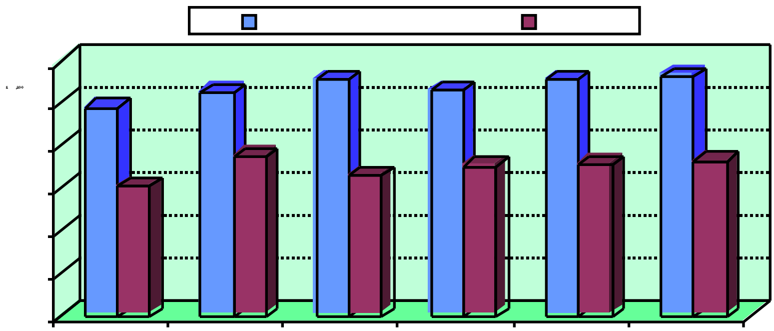

Figure 13: Average seed yield (kg/ha) of improved vs. local varieties

b. Assessment of cost of production and profitability: *The cost of production included all variable cost items, such as human labour, animal power, power tiller, seed, manure, fertilizers, insecticides, etc. Average cost of production of the farmers who followed improved technologies was US$171 (US$1 = 57.00 Taka) compared to US$158 with traditional practices. However, when cash cost was considered, the cost of production per hectare was found to be US$54 for block farmers and US$56 for non-block farmers. Cash cost was found to be* *slightly higher when no improved technology was applied, because non-block farmers used more hired labour and animal power.*

The average benefit-cost ratio on full cost basis was 1.80 for farmers who used improved production technologies, and 1.35 for those who did not. On a cash cost basis, the ration was 5.77 for block farmers and 3.89 for non-block farmers.

c. Overall impact: *With the cultivation of improved varieties and adoption of appropriate production technologies, lentil production in Bangladesh has raised 28,000 t per year (Bakr and Afzal, 2003). With a farm-gate price of US$450/t (Taka 25,650/t), the value of the increased yield is US$12.6 million, a considerable annual saving in foreign exchange. It has been estimated that from 2002, Bangladesh imported lentil only US$5 million's worth compared to the annual import value of about US$17.6 million. With rapid dissemination and faster adoption of improved technologies, lentil production and productivity in Bangladesh will further increase in the coming years. What's more, the increased production is being eaten by the people of Bangladesh, mostly by the rural poor, and thus contributing to improved nutrition, particularly in increased protein, Zn, Fe, and β-carotene. Nutritionally, children and pregnant women are the major beneficiaries. The increased straw production of the improved varieties represents another value in the feed-scarce country.*

An impact analysis found that the extra income earned from cultivation of improved varieties was used by farmers to buy clothes (15.6%), personal items (19.5%), purchase of rice and other foods (9.9%), cultivation of the next crop (16.6%), children's education (14.8%), medical treatment (13.7%), to pay down loans (5.8%), and other purposes (4.1%), such as purchase of cattle, threshers, to make brick houses, and repair farm implements.

Figure 14a: Adoption of improved variety-A Farmer with researchers and extensionist

Figure 14b: Adoption of improved varieties-A farmer with his crop

Figure 15: A farmer, Md. Altaf Hussain in his field of Barimasur-4 lentil variety in the village Ghanna. He expects to harvest 2.4 t/ha of lentil. A team comprising of DG, ICARDA, DG, BARI, DG, Extension and other researchers and extensionists visited his field on 13 February 2004

X. SECRETS OF SUCCESS

The following factors played a crucial role in increasing lentil production in Bangladesh. As horizontal expansion is virtually impossible due to competition from other winter crops, increased productivity was the goal, and the overall success is attributed to the following:

1. *Improved, disease resistant varieties with matching phenology that fit the short winter cropping system.*
2. *Economically viable, sustainable improved lentil production technologies, developed by strong and vibrant lentil research team.*

3. *Support extended by ICARDA and the Government of Bangladesh for research and development, particularly through the Technology Transfer Pilot Project.*
4. *Effective implementation, monitoring, and periodic evaluation of the technology transfer programs.*
5. *Extensive transfer of technology and field extension programs, well supported by input outlets at the village level.*
6. *Close linkage with ICARDA in research, particularly in varietal development and human resource development.*
7. *Extensive publicity programs undertaken by the Pilot Project and government-supported mass media.*
8. *Domestic consumption and market demand, which maintained prices.*
9. *An integrated, effective, efficient, and functional farmer-researcher-extension-policy interface.*

The example of Bangladesh in collaboration, technology development, dissemination and impact assessment may serve as an example, which can be followed by other national programs with similar conditions.

XI. EPILOGUE

Bangladesh has succeeded in increasing lentil production through sustained research and development efforts by the national program, with collaoration of regional and international organizations, thereby leading to selection of high yielding varieties. Bangladesh's success in increasing lentil production – and thus improving nutrition and reducing foreign exchange expenditures – could be an example for other South Asian countries, which together account for about half of world lentil production. The success, which was made possible due to the commitment of researchers, extension workers and farmers, was the result of development and adoption of agronomic packages built around *improved varieties. Further adoption of relay lentil (zero tillage) cropping and cultivation in non-traditional areas will further boost production.*

Government support for research and development remains critical, however, research priorities and activities need to be refined in the context of farmers' demand. In this context, more recent development under the APAARI umbrella through the regional research networks such as CLAN, with the newly proposed South Asian Network for Lentil Improvement [SANLI], will go a long way to accelerate R & D activities in lentil improvement for the benefit of the NARS in the Asia-Pacific region.

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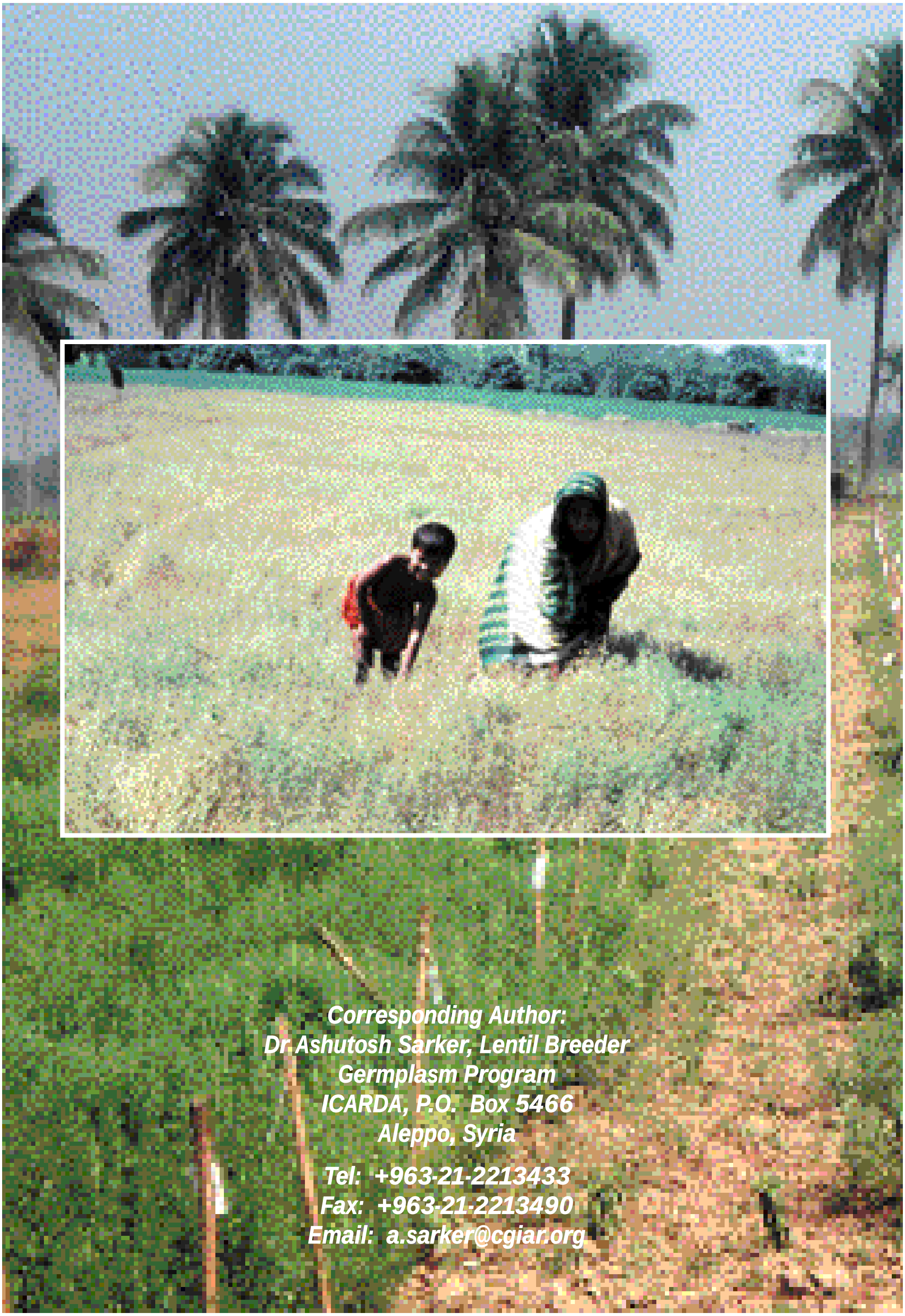

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