Short Duration Mungbean: A New Success in South Asia

Asia-Pacific Association of Agricultural Research Institutions
c/o FAO Regional Office for Asia and the Pacific
Bangkok, Thailand

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Foreword

Pulses are an important protein source for Asian people, many of whom largely depend upon cereals and pulses for their daily requirements. South Asian countries together are the world's largest producers and consumers of pulses comprising mainly chickpea, pigeonpea and mungbean. Mungbean, being high in protein and easily digestible, constitutes a balanced diet in combination with cereals. Moreover, being one of the most short duration legumes, it has great scope of fitting in between rice-wheat cropping system in entire Indo-Gangetic plains. Unfortunately, the production of pulse crops over the past few decades has declined in almost all traditionally pulse growing countries like India, Nepal and Bangladesh. Accordingly, the need for increasing production and productivity of pulse crops, including mungbean, is being felt acutely throughout the region.

AVRDC – The World Vegetable Center has played a significant role in evolving improved vegetables and mungbean germplasm in Asia. Working with national research partners in nearly two dozen Asian countries, AVRDC programs have led to the release of a large number of varieties adapted to local conditions, thus benefiting millions of farmers and consumers. The new mungbean varieties are high yielding as well as early and uniform in maturity. These varieties have bold seeds and possess resistance to major diseases, including yellow mosaic virus. Expectedly, the improved varieties have been adopted widely by the farmers in South and South-east Asian countries. This publication "Short Duration Mungbean: A New Success in South Asia" by Dr. M.L. Chadha relates to the development, performance and adoption of mungbean varieties, which successfully address the major constraints to production in the region.

The Asia-Pacific Association of Agricultural Research Institutions (APAARI) has been publishing success stories on various aspects of agricultural research and development that have large scale impact and have brought tangible benefits to both the farmers and consumers alike. So far, more than 40 success stories from the region on diverse topics have been published by APAARI, details of which are available on our website: www.apaari.org. It is felt that dissemination of such success stories will help in wider adoption of new technologies, thus benefiting largely the resource poor farmers.

We are thankful to Dr. Chadha for synthesizing this valuable information relating to efforts of AVRDC in improving mungbean, an important pulse crop of Asia. It is our expectation that APAARI members and stakeholders will find this publication both informative and of practical value.

(Raj Paroda)
Executive Secretary
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Contents

Acronyms

AVRDC	Asian Vegetable Research and Development Center (now known as AVRDC – The World Vegetable Center)
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
BSMRAU	Bangabandhu Sheik Mujibur Rahman Agricultural University
CG	Control Group
CIMMYT	International Maize and Wheat Improvement Center
DAS	Days after sowing
DFID	Department for International Development
FAO	Food and Agricultural Organization of the United Nations
FORWARD	Forum for Rural Welfare and Agricultural Reform for Development
GBPUAT	G.B. Pant University of Agriculture and Technology
GRSU	Genetic Resources and Seed Unit
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IIPR	Indian Institute of Pulses Research

IMN	International Mungbean Nursery
Li-BIRD	Local Initiatives for Biodiversity, Research and Development
MYMV	Mungbean yellow mosaic virus
N	Nitrogen
NARC	Nepal Agricultural Research Council
NGO	Non Government Organization
NIAB	Nuclear Institute for Agriculture and Biology
NPK	Nitrogen Phosphorus Potash
NSC	National Seed Corporation
P	Phosphorus
PARC	Pakistan Agricultural Research Council
PAU	Punjab Agricultural University
PSSC	Punjab State Seed Corporation
R&D	Research and Development
RCSA	AVRDC – The World Vegetable Center Regional Center for South Asia
Rs.	Rupees
RSSC	Rajasthan State Seed Corporation
SAVERNET	South Asian Vegetable Research Network
t/ha	Ton per hectare
TNAU	Tamil Nadu Agricultural University
UK	United Kingdom
USAID	United States Agency for International Development

1. Introduction

Mungbean is a major pulse crop in Asia. National partners in Bangladesh, Bhutan, China, India, Myanmar, Nepal, Pakistan, Sri Lanka and Thailand collaborated with AVRDC – The World Vegetable Center, using an integrated, interdisciplinary approach to research and develop improved mungbean varieties and technologies. The effort aimed to resolve the major constraints limiting mungbean production. The new varieties had short maturity duration (55 to 65 days), high yield (2 t/ha), uniform maturity, bold seeds (5 to 6 gram per 100 seeds) and resistance to Cercospora leaf spot, powdery mildew, and *Mungbean yellow mosaic virus*. Improved varieties such as 'SML 668' were readily adopted by farmers in the participating countries. The total area planted to improved varieties reached almost 3 million hectares, benefiting 1.5 million farmers. Average yield increased by about 300 kilograms per hectare. By including mungbean in rice or wheat rotations, the additional benefit to farmers was estimated to be US$ 150 million. Mungbean consumption increased by 22 to 66% improving the health especially of anemic women and children.

Mungbean: A pulse with promise

Mungbean [*Vigna radiata* (L.) Wilczek], subgenus *Ceratotrpis*, is an indigenous vegetable legume and one of the most important pulse crops in South and Southeast Asia (AVRDC, 1998). Rich in easily digestible protein (24%), mungbean adds much-needed diversity to the cereal-based diets of the poor (Thirumaran and Seralathan, 1988). Mungbean contains vitamin A (94 mg), iron (7.3 mg), calcium (124 mg), zinc (3 mg) and folate (549 mg) per 100 g dry seed. It is consumed as *dhal* in South Asia, and food products such as fried snacks, desserts, and bean sprouts. Sprouts, which are a good source of vitamin C (8 mg per 100 g), can be produced year-round at home or commercially (Calloway *et al.*, 1994; Gopalan *et al.*, 1989).

As a result of the Green Revolution, the rice-wheat cropping system now dominates the important food production areas of the Indo-Gangetic Plains and the Peninsular Region. About 60% of the total cropping area is under rice and wheat; these two staple grains have replaced more than 25 different crops in both the *Kharif* (rainy) and *Rabi* (summer) growing seasons. This system provides good returns to farmers and strengthens food security, but sustainability is declining due to the lack of any adjustment in crop rotation although options for such adjustment exist. The situation in the Indo-Gangetic Plains is further aggravated as rice and wheat together account for 82% of the total area devoted to food grain production. In Punjab and West Bengal, more than 95% of the area of food grain production is now under rice and wheat. This phenomenon relegates pulses and coarse cereals to marginal lands. In Bihar, Haryana, Punjab, Uttar Pradesh, and West Bengal in India, the area planted to pulses declined from 8.03 million ha in 1971-75 to 5.22 million ha in 2004, giving way to rice in *Kharif* and wheat in *Rabi* seasons.

Due to continuous cultivation of cereals in intensively cropped areas, nutrient (NPK) uptake increased by 663 kg against the applied 400 kg/ha to yield 8.8 t/ha in rice-wheat rotation, and 438 kg against the applied 358 kg/ha to yield 6.3 t/ha in rice-rice rotation (Ali and Kumar, 2004). Furthermore, the optimum NPK ratio of 4:2:1 widened to 8.5:3.1:1 at the national level; the western Indo-Gangetic Plains shows maximum distortion (37.1:8.9:1) where rice and wheat are grown in sequence on 82% of the total cropped area (Ali and Kumar, 2004). Inadequate use of organic fertilizers is another area of concern, as less than one ton of organic matter per ha is being added to the soil. This is leading to a rapid decline in the organic matter content of soils, particularly in Punjab (0.2% carbon content) (Ali and Kumar, 2004). Planting rice two months before the onset of the monsoon has dangerously lowered the water table at the rate of 300 mm per year. Excessive and indiscriminate use of irrigation water causes salinity to increase and water to stagnate.

After the harvest of wheat and before the transplanting of rice, the land remains fallow for 65-70 days (late March/April to early July). This period could be used to raise a catch crop of summer mungbean. A low input, short duration, high value crop, mungbean fits very well into rice-wheat cropping systems and other crop rotations. Mungbean fixes nitrogen in the soil, requires less irrigation than many field crops to produce a good yield, and helps maintain soil fertility and texture. Adding mungbean to the cereal cropping system has the potential to increase farm income, improve human health and soil productivity, save irrigation water, and promote long-term sustainability of agriculture.

Traditional mungbean varieties were long duration (70-80 days to maturity) and non-synchronizing. To include mungbean in rice-wheat cropping systems, farmers needed short-duration varieties. In the Peninsular Region, winter season mungbean (November sown) cultivated in rice fallows should be mid-late in maturity (70-80 days), tall, vigorous growing (to smother weeds) and resistant to powdery mildew. Late sown mungbean in rice fallows (January-March) should be early maturing (60-65 days) with resistance to *Mungbean yellow mosaic virus* (MYMV).

In general, the new mungbean varieties are resistant to MYMV, more compact, having a high harvest index, reduced photoperiod sensitivity, early (55-60 days) and synchronous maturity, bear pods at the top in bunches, have long pods with bold, shiny seeds, and determinate growth habits. Drooping pods with thick pod coats are desirable, as they are less damaged by rains and less prone to shattering at maturity (Bains *et al.*, 2007). Genotypes with these plant characteristics are more suited to rice fallows during summer. For maximum productivity, vegetative growth should terminate with flowering and assimilates should be channeled into production of more number of pods (Saini and Das, 1979).

2. The Role of AVRDC – The World Vegetable Center in Mungbean R&D and Promotion

Forty years ago mungbean was still a wild crop relegated to marginal lands and cultivated with minimal inputs. AVRDC– The World Vegetable Center (the Center) recognized its potential to feed protein-hungry populations, improve the nutritional quality of diets, and diversify modern high-yielding cereal cropping systems. Soil deterioration, depletion of water tables, salinization, increased pests and diseases and environmental pollution due to continuous cropping of cereals can be overcome by diversifying crop rotations with mungbean (Shanmugasundaram, 2006). Presently, AVRDC is the only international agricultural research center with a mandate on mungbean and plays an important role in mungbean improvement. The Center's genebank holds 11,000 well-characterized *Vigna* spp. accessions comprising the world's largest *Vigna* germplasm collection, which including 13 *Vigna* spp. (Table 1). Because a large collection poses difficulties in germplasm evaluation, distribution and regeneration, the Genetic Resources and Seed Unit (GRSU) of AVRDC has assembled a core collection of accessions. The main objective of mungbean improvement at AVRDC is to develop short duration (55 to 65 days), synchronous maturing (for single harvest), bold and large seeded (>5 g for 100 seeds), and high and stable yielding (2.5 t/ha) varieties with reduced sensitivity to photoperiod and temperature, and with resistance/tolerance to major biotic and abiotic stress (such as MYMV, Cercospora leaf spot, and powdery mildew). Every year selected elite lines and superior accessions from different countries are evaluated for different traits in the International Mungbean Nursery (IMN) for adaptability, pest and disease resistance, and other important agronomic and yield traits in many countries.

Table 1. Number of *Vigna* spp. accessions in AVRDC's genebank as of April 2009

Species	Subspecies/Variety	No. of Accessions
Vigna aconitifolia		22
Vigna angularis		2396
Vigna caracalla		1
Vigna glabrescens		3
Vigna luteola		2
Vigna marina		3
Vigna mungo		512
Vigna mungo	var. *silvestris*	250
Vigna parkeri		1
Vigna radiata	var. *radiata*	5,900
Vigna radiata	var. *sublobata*	5
Vigna trilobata		2
Vigna umbellata		290
Vigna unguiculata		360
Vigna unguiculata	subsp. *sesquipedalis*	479
Vigna unguiculata	subsp. *unguiculata*	313
Vigna vexillata		1
Vigna spp.		193
Total		10,733

AVRDC focused its mungbean intervention on Bangladesh, Bhutan, China, India, Nepal, Myanmar, Pakistan, Sri Lanka and Thailand. The foundation for this project was laid as early as 1972, however, AVRDC initiated the *Mungbean yellow mosaic virus* (MYMV) network after the international MYMV Expert Consultation Workshop in 1991 in Bangkok and the AVRDC/USAID project in Bangladesh as well as the South Asian Vegetable Research Network (SAVERNET) in 1992. The specific components of the project "Promotion of mungbean research outputs for farmer adoption in

South Asia" commenced by the Center in April 1997 with financial support from Department for International Development (DFID) of UK in six South Asian countries; it continues today with support from various agencies. The intervention included the key players listed in Table 2, along with extension officers, NGOs, and mungbean farmers in each country.

Table 2. The mungbean intervention's stakeholders.

Area	Organization
Pan-Asia	• AVRDC – The World Vegetable Center
	• AVRDC Asian Regional Center (ARC)
	• AVRDC Regional Center for South Asia (RCSA)
China	• Chinese Academy of Agricultural Sciences
Bangladesh	• Bangladesh Agricultural Research Council (BARC)
	• Bangladesh Agricultural Research Institute (BARI)
	• Bangabandhu Sheik Mujibur Rahman Agricultural University (BSMRAU)
	• AVRDC–USAID Bangladesh Project
Bhutan	• Agricultural Department, Government of Bhutan
India	• Indian Council of Agricultural Research (ICAR)
	• Indian Agricultural Research Institute (IARI)
	• Indian Institute of Pulses Research (IIPR), Kanpur
	• Punjab Agricultural University (PAU), Ludhiana
	• G. B. Pant University of Agriculture and Technology (GBPUAT), Pantnagar
	• CCS Haryana Agricultural University, Hisar
	• Tamil Nadu Agricultural University (TNAU), Coimbatore
	• Rajasthan Agricultural University, Sriganganagar, Rajasthan
	• Avinashilingam Deemed Home Science University for Women, Coimbatore
Myanmar	• International Rice Research Institute (IRRI), Food and Agriculture Organization of the United Nations (FAO) office

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Area	Organization
Nepal	• Nepal Agricultural Research Council (NARC) • Forum for Rural Welfare and Agricultural Reform for Development (FORWARD) • Local Initiatives for Biodiversity Research and Development (LI-BIRD) • National Grain Legume Research Program • International Maize and Wheat Improvement Center (CIMMYT) office
Pakistan	• Pakistan Agricultural Research Council (PARC) • National Research Center, Islamabad • Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad • Ayub Agricultural Research Institute
Sri Lanka	• Field Crops Research and Development Institute, Maha Illuppallama • Department of Agriculture
Thailand	• Department of Agriculture • Department of Agricultural Extension • Kasetsart University • Prince Songkla University • Khon Kaen University

3. Variety Improvement Program

Traditional mungbean cultivars cultivated in Asia had long growth duration (90-110 days), indeterminate growth habit, and were multiple harvesting types. They were low yielding (400 kg/ha), small seed-sized, susceptible to MYMV and insects. Therefore, the Center directed its research activities on the development of cultivars with short growth duration (55 to 65 days), high yield potential (up to 2000 kg/ha), synchronous maturity (single harvest), resistance to MYMV, Cercospora leaf spot, and powdery mildew, and the bold shiny seeds preferred by the market.

Varietal trails were conducted to screen ideal types (Fig. 1). With short maturity periods, these varieties fit well as a catch crop into various cereal-based rotations such as rice-mungbean, rice-wheat-mungbean, rice-potato-mungbean, maize-mungbean, maize-mungbean-wheat, etc. There are further possibilities to grow them as intercrops with cotton, maize, and with vegetables. Farmers invariably preferred the improved varieties over the existing local cultivars, due to various agronomic and postharvest attributes.

Punjab Agricultural University in India released 'SML 668' a variety developed from AVRDC line NM 94, which gives better yield performance (upto 2.5 t/ha), synchronous and early maturity, bold and shining seeds and is also tolerant to MYMV disease (Fig. 2). The variety was recommended for cultivation in both summer and *Kharif* seasons. It is the first ever variety approved for general cultivation in both seasons in Punjab. New breeding populations of other promising lines were generated and evaluated for the continuity of future research work on mungbean. In November 2009, PAU identified and released 'SML 832,' a new high yielding, MYMV resistant spring/summer mungbean variety. (Fig. 2)

Fig. 1. Varietal evaluation for MYMV resistance and yield performance (*contd...*)

Fig. 1. Varietal evaluation for MYMV resistance and yield performance

Fig. 2. Variety 'SML 668' (a) and 'SML 832' (b)

In 2005-06, AVRDC sanctioned another project “Popularization of extra-short duration mungbean cultivars for poverty alleviation and improved nutrition in Bihar and Rajasthan, based on Punjab model.” Several high-yielding mungbean varieties based on AVRDC lines were released in this period (Table 3). To maximize the yield potential, improved production and protection technologies were developed and tested at PAU, Ludhiana; Rajasthan Agricultural University Research Station, Sriganganagar; Rajendra Agricultural University, Pusa, Bihar; Bangladesh Agricultural Research Institute (BARI) and National Agricultural Research Institute (NARI), Nepal.

Cooperators around the world including IARI, GBPUAT, PAU in India, BARI, and BINA in Bangladesh, NIAB in Pakistan, and agricultural research institutions in Nepal and Sri Lanka have identified, released and popularized 112 varieties based on AVRDC lines, including 24 varieties in South Asia (Table 3). These improved varieties are well-adapted to the spring, summer and autumn seasons in the low hills and *terai* agroecosystems of Nepal, and in the Indo-Gangetic Plains (Khanal *et al.*, 2004).

Table 3. AVRDC mungbean cultivars released in South Asia as of January 2009

S. No.	Local name	AVRDC ID#	Parentage	Year of release	Country
1.	Maash - 2008	NM 92	VC 2768B VC 6141-36	2008	Afghanistan
2.	Mai-2008	NM 94	VC 2768A VC 6141-36	2008	Afghanistan
3.	BARI Mung-5	NM 92	VC 2768B VC 6141-36	1997	Bangladesh
4.	BU Mug 1	VC 6372(45-8-1)	VC 6370-92 [VC 2768A x (VC 1973A V 6601)]	2000	Bangladesh
5.	BU Mug 2	VC 6370(30-65)	VC 2768A VC 6141-36	2001	Bangladesh
6.	KPS 1	VC 1973A	CESID-21 EG-MG-16	2001	Bhutan
7.	-	BARI Mung-2		2002	Bhutan
8.	KPS 2	VC 2768A	VC 1481A VC1628A	2002	Bhutan
9.	M 986	V 3554		1981	India
10.	SML 668	NM 94	VC 2768A VC 6141-36	2000	India
11.	Pusa Vishal	NM 92	VC 2768B VC 6141-36)	2000	India
12.	Pant Mung 5	VC 6368(46-40-4)	VC 6370-92 VC 6141-96	2002	India
13.	Pusa 105	VC 1137-2B	VC 1025 VC 1000	1984, 1983	India
14.	Pusa 101	V 3484		1984, 1983	India
15.	Kalyan	NM 94	VC 2768A VC 6141-36	2006	Nepal
16.	Prateeksha	VC6372	VC 6370-92 VC 6371-93	2006	Nepal

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S. No.	Local name	AVRDC ID#	Parentage	Year of release	Country
17.	NIAB MUNG 54	VC 6141-54	VC 1973A 6601 F21 Gamma ray treated	1990	Pakistan
18.	NIAB MUNG 51	VC 6370-92	VC 1973A 6601 F1 Gamma ray treated	1990	Pakistan
19.	NM 92	VC 6370-92	VC 2768B VC 6141-36	1992	Pakistan
20.	NIAB MUNG 92	VC 6370-92	VC 2768B VC 6141-36	1996	Pakistan
21.	NM 51	VC 6370-92	VC 1973A V6601		Pakistan
22.	NM 54	VC 6141-54	VC 1973A V6601		Pakistan
23.	Type 77	VC 1131-B-12-2-B	EG-MG-16 ML-3 EG-MG-16	1982	Sri Lanka
24.	MI-6	VC 6173B-20G	VC 1560A VC 6370-92	2004	Sri Lanka

VC = Vigna cross bred line from AVRDC.

V = accession or introduction.

4. Improved Package of Agro-technologies

Agronomic management inputs increase crop yields and ensure efficient use of farm resources, resulting in short-term as well as long-term gains for farmers. To exploit the high yield potential of newly introduced improved mungbean varieties as catch crop in rice-wheat systems, agro-technologies such as planting time, seed rate, seed priming, plant population density, tillage versus non-tillage, weed control, fertilizer requirement, irrigation requirement, and stress management were refined. Agronomic studies in Punjab and various other locations in India and Bangladesh were conducted to exploit the high yield potential of improved varieties in rice-wheat cropping systems. Leaflets on raising summer mungbean were prepared and distributed to farmers in Punjab (Fig. 3).

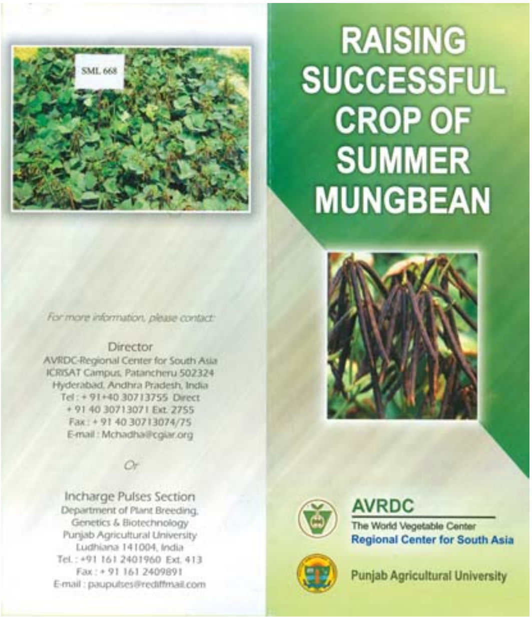

Fig. 3. Handout on mungbean package of practices

Sowing Methods: Good seedbed preparation and deep tillage, particularly under rainfed conditions, helps to conserve soil moisture and eradicate weeds. Sowing summer mungbean on raised bed (67.5 cm) with three rows at 20 cm gives better yield than flat beds with row-to-row spacing (AVRDC, 2006). No tillage was observed to provide higher yield of 'SML 668' in summer over tillage and tillage plus wheat straw incorporation (Fig. 4). The no-tillage rice stubble cultivation is becoming popular in Punjab for the sowing of wheat (Kaul and Singh, 2002). No-tillage (direct seeding), results in quantitative and qualitative improvement in soil structure due to the least soil disturbance (Baker *et al.*, 1996). Furthermore, energy output and energy input ratio is higher in no-tillage as compared to conventional tillage (Gautam, 2000). No-tillage seeding saves time required for field preparation, money (Rs.1500-1750/ha) and energy, and no-tillage produces yield equivalent to tillage treatment (Sekhon *et al.*, 2004, 2007).

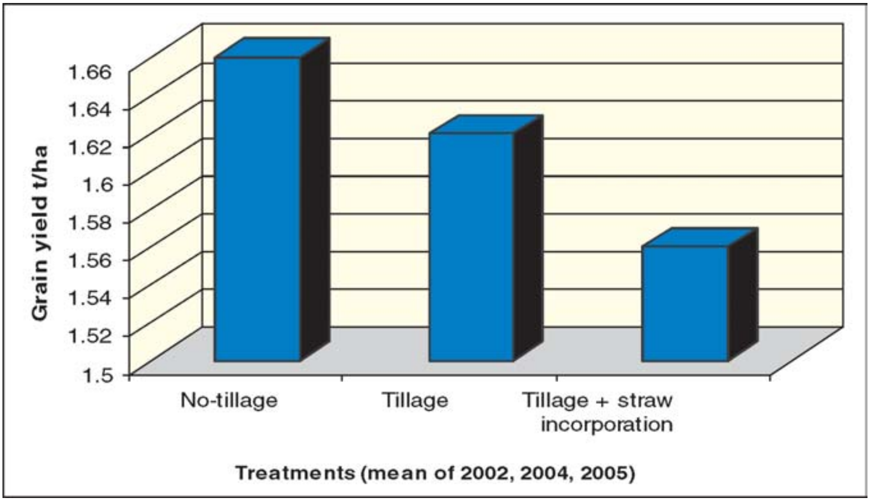

Fig. 4. Effect of tillage and straw incorporation on summer mungbean grain yield

Sowing Time: Mungbean is photoperiod sensitive. An extended or reduced vegetative period may create imbalances during vegetative and reproductive phases that influence crop productivity. The optimum sowing time can realize the yield potential of an improved variety (Dhingra and Sekhon, 1988). Ideal spring season planting time is the first fortnight of March and for summer mungbean, the first fortnight of April. Crops planted later may suffer heavy losses due to reduced pod and seed size, and maturity may coincide with the monsoon rain, which causes deterioration in grain quality (Sekhon *et al.*, 2007). In Punjab, the best time for sowing summer mungbean is from March 20 to April 10 (Table 4). In *Kharif* season, significantly higher yield can be recorded with 'SML 668' by sowing on July 10 and 25 compared with 10 August, allowing about 70-75 days to maturity (Sekhon *et al.*, 2004).

Planting on 15 February in Barisal, and on March or April in Jessore and Dinajpur, Bangladesh produced higher yield. Late planting generally reduced mungbean seed yield; but the reduction was less in 'BUmug 1' and 'BUmug 2.' Varieties differed significantly in the effect of planting arrangement on mungbean yield (Hamid *et al.*, 2004).

Table 4. Effect of date of sowing on summer mungbean maturity and grain yield

Date of sowing	Maturity (days)		Mean	Grain yield (t/ha)		Mean
	2003	2004		2003	2004	
1 March	69	69	69.0	0.92	1.12	1.02
20 March	66	68	67.0	1.53	1.72	1.63
30 March	64	70	67.0	1.51	1.88	1.69
10 April	62	64	63.0	1.43	1.85	1.64
20 April	61	62	61.5	1.31	1.57	1.44
30 April	60	61	60.5	1.23	1.24	1.23
CD (P=0.05)	-	-	-	0. 20	0.18	-

Seed Rate: For deciding seed rate, growing season, cropping system, average seed size (100-seed weight), vigour of genotype, soil type and environmental conditions are the major factors (Dhingra and Sekhon, 1988; Dhanjal *et al.*, 2000). Low plant populations always give poor yields and excessive plant populations are disadvantageous and uneconomical. As a sole crop during *Kharif* season, 20-25 kg seeds/ha and during summer season, 35-38 kg seeds/ha is required to maintain the desired plant population (Ali and Kumar, 2004). Optimum seed rate for 'SML 668' in summer season is 37.5 kg/ha and for rainy season crop is 30 kg/ha with the spacing of 20.5 cm × 10 cm and 30 cm × 10 cm, respectively (Fig. 5) (Sekhon and Singh, 2005; Sekhon *et al.*, 2007). A row spacing of 45 cm during *Kharif* season and 20 cm during spring season/summer season is ideal for mungbean. 40 plants/m^2 at 25 cm × 10 cm spacing yield significantly higher than 33 plants/m^2 (Sekhon *et al.*, 2007). The large-seeded determinate cultivars such as 'Pusa Vishal' and 'SML 668' can give higher yield at higher plant population densities up to 500,000/ha (20 × 10 cm).

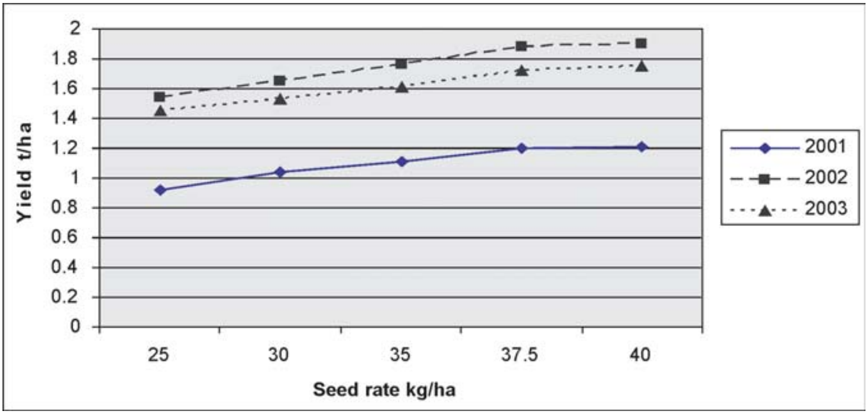

Fig. 5. Effect of seed rate on the grain yield of summer mungbean

'BUmug 2' produces the highest yield at 30 cm × 5 cm and 'BARImung 2' at 20 cm × 10 cm planting configurations in Bangladesh (Hamid *et al.*, 2004).

Fertilizer and Irrigation Requirements: Application of the recommended dose of fertilizer (12.5 kg N and 40 kg P) was found to be appropriate (Fig. 6). Application of molybdenum 1-4 g/kg of seeds also enhanced the grain yield (25.5%) (Ali and Kumar, 2004; Srinivasan *et al.*, 2007). The crop requires 3 to 5 irrigations, depending upon the soil and climate. Irrigations after sowing, at flowering, and at seed filling stages are essential to produce high yield. Irrigations given at 15, 25, 35, and 45 days after sowing (DAS) resulted in significantly higher grain yield of mungbean (Sekhon *et al.*, 2004; Siag and Prakash, 2007).

On loamy sand soil, four irrigations (25, 32, 41 and 49 days after sowing) in summer season followed by the termination of last irrigation at 47 DAS shows synchronous crop maturity. During rainy season, missing irrigation at the pod formation stage in the absence of rainfall drastically reduces yield compared to the irrigated crop (Sekhon *et al.*, 2004).

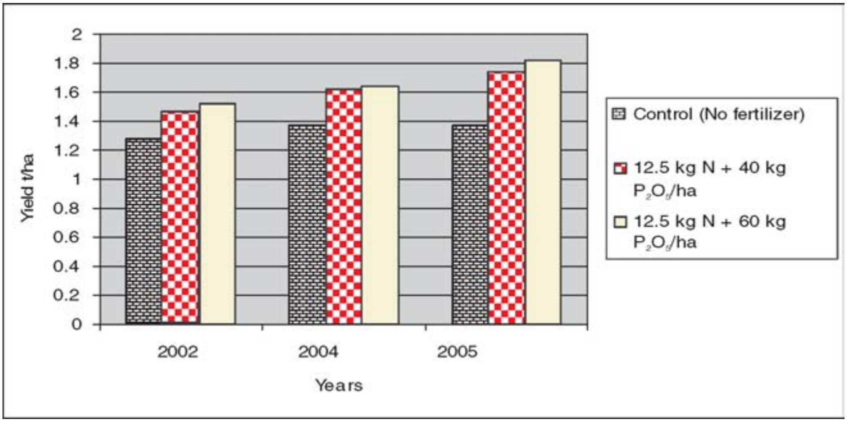

Fig. 6. Effect of fertilizer on the grain yield of summer mungbean

Crop Protection Measures: Among 198 globally reported mungbean insect pests, 64 species attack the mungbean crop in India (Lal, 1985), including thrips (*Megalurothrips distalis*) and gram pod borer (*Helicoverpa armigera*). Whitefly (*Bemisia tabaci*), Bihar hairy caterpillar (*Spilosoma obliqua*), green semi-looper (*Anomis flava*), legume pod borer (*Maruca vitrata*), bean mite (*Polyphagotarsonemus latus*) and black aphid (*Aphis craccivora*) are the most critical insect pests of summer mungbean that lead to heavy losses and sometimes total failure of the crop.

Improved management technology including soil application of granular insecticides such as aldicarb, phorate, and carbofuran at 10 kg/ha during spring has proved to be highly effective against whitefly and other sucking pests. Triazophos (hostathion 40 EC) at 1500 ml/ha and seed treatment with thiomethoxam (Actara 25 WG) at 2 g/kg seed + foliar spray of triazophos (hostathion 40 EC) at 0.04% has been reported to give the best control of whitefly and other sucking pests in mungbean (rainy season) (Kooner *et al.*, 2004). Spray of dimethoate (rogor 30 EC) 250 ml or malathion 50 EC (malathion) 250 ml or oxydemeton methyl (Metasystox 25 EC) 300 ml in 200-250 l/ha water at flower initiation helps in reducing thrips (Sekhon *et al.*, 2004). Quinalphos (ekalux 20 AF) 2.0 l or endosulfan (thiodan 35 EC) 2.5 l/ha using 200-250 l/ha water spray gives good control of pod borer. During rainy season, application of indoxacarb (avaunt 14.5 SC) at 500 ml and endosulfan (thiodan 35 EC) at 2.5 l/ha has been found to give better control of *Maruca vitrata*. Reduced plant population also helps in reducing aphid population as the pest population increases with higher seed rate of 37.5-40 kg/ha compared with low seed rate (25-30 kg/ha) (Kooner *et al.*, 2007).

5. Production Economics and Impact

From the past three decades of research, the potential yield improved to 2.7 t/ha in the experimental field. High yielding, early, synchronously maturing, bold seeded, short growth duration mungbean varieties with resistance to MYMV, Cercospora leaf spot and powdery mildew constitute more than 25% of world mungbean production (Shanmugasundaram, 2006). Cooperators in about 28 countries released a total of 112 mungbean varieties. Mungbean has been successfully introduced in the rice-wheat, rice-potato, and other cropping systems during the fallow period between cereal crops in the Indo-Gangetic Plains.

The estimated area under mungbean cultivation has increased to 4 million hectares across the South Asian countries, with a total production of about 1.75 million tons.

In India, mungbean is cultivated on an area of 3.34 million ha with production of 1.06 million tons and average productivity of 317 kg/ha (Dixit, 2005). In the northern states, the mungbean crop is grown as an intercrop with sorghum, cotton, maize, millets, pigeonpea, sunflower, and sugarcane, and also as a monocrop in *Kharif* season. Mungbean is grown as a *Rabi* crop in rice fallows or rice-rice systems in southern and eastern regions. In the Indo-Gangetic Plains, it is grown as spring and summer crop. Spring crop may be sown in the third week of March after the harvest of mustard or potato. Summer crop is sown after the harvest of wheat in mid-April. Spring/summer mungbean is grown in rice-mustard/potato-mungbean rotations in the western Indo-Gangetic Plains and rice-mustard-mungbean in the eastern Indo-Gangetic Plains.

In South Asia, the area under pulses in general (including mungbean) decreased from 27 to 24 million ha from 1963 to 2003 although the production increased from 13.5 to 15 million tons during the same period (Jat *et al.*, 2006). Due to the introduction of improved short duration, high yielding disease resistant mungbean, the area and production of mungbean has increased in selected countries. The average annual growth rate in production of mungbean from 1985 to 2000 in respective countries is: Bangladesh–9.5%, India–0.3%, Pakistan–5.6%, Sri Lanka–6.9%, Myanmar–23.5%, Thailand–0.8% and China–2.4%. The mungbean production in Asia increased 12% from 2.3 million tons in 1985 to 3.1 million tons in 2000 (Weinberger, 2003). In India, it is cultivated on 3.2 million hectares, and production is 0.95 million tons (Singh, 2008). As of July 2009, the area under *Kharif* mungbean in India increased by 1,924,000 ha (Shah, 2010). In Pakistan, mungbean production has increased tremendously, from 31.8 thousand tons in 1980-81 to 177.7 thousand tons in 2007-08 with and increase in area from 67,000 to 247,400 ha (Anonymous, 2007-08).

In Sri Lanka, area and production of mungbean have decreased by 3,250 ha and 2,790 tons in 2000 from 13,490 ha and 12,240 tons in 1998 (Anonymous, 2009).

The estimated area under AVRDC's improved mungbean varieties has increased from 100,000 to 200,000 ha in Pakistan, 15,000 to 70,000 in Bangladesh, from 284,500 to 550,000 ha in India and 12,000 ha in Nepal (Shanmugasundaram, 2007). Improved mungbean varieties occupy almost 90% of the mungbean area in Pakistan (Ali *et al.*, 1997), and around 70% in Bangladesh (Chadha *et al.*, 2009). In Punjab, India the improved variety, 'SML 668' was planted to 95% and 60% of the mungbean areas in the summer and rainy seasons of 2006, respectively. The estimated area planted to mungbean variety 'SML 668' and 'Pusa Vishal' during 2008 in

Punjab, Rajasthan, Haryana, was about 60,000, 70,000, and 50,000 ha, respectively. Nepal released three and Sri Lanka released two improved varieties; however, the extent of their adoption is unavailable.

In Punjab, during 2006 summer and rainy season more than 95% and 60% area was under 'SML 668,' respectively. The estimated area planted to 'SML 668' and 'Pusa Vishal' in Punjab, Rajasthan, Haryana, has increased to 60,000, 70,000, and 50,000 ha, respectively during 2008 (Chadha *et al.*, 2009). By observing the success of mungbean in Punjab, the farmers in the adjoining states of Haryana, Rajasthan, Uttar Pradesh and Bihar began cultivation of 'SML 668' on a large scale (Fig. 7) and the government and private agencies of these states have taken up the seed production program (Singh *et al.*, 2007).

The value of the surplus generated due to improved mungbean varieties and intensive efforts of mungbean technology dissemination in Pakistan has been estimated by Afzal *et al.* (2004) to be around US$ 192 million. In an on-farm trial conducted at Dakha village in Punjab, summer mungbean sown after wheat recorded a total productivity of 11.8 t/ha in rice-wheat system and 12.96 t/ha in rice-wheat-summer mungbean system (Fig. 8). Farmers in Punjab are earning about Rs. 25,000-35,000/ha by growing 'SML 668' in summer (AVRDC, 2006) and the net returns over variable costs in rice-wheat-summer mungbean were Rs.10,200/ha higher than the rice-wheat system (Fig. 9) (Sekhon *et al.*, 2007). The average net returns for summer mungbean after wheat and potato varied from Rs. 26,305/ha to Rs. 26,950/ha, respectively. Some farmers in Punjab were able to get higher net return up to Rs. 52,000 and Rs. 43,000/ha over variable costs after potato and wheat, respectively, depending upon market price fluctuation (Table 5).

Fig. 7 (a,b). 'SML 668' at farmers' field in Punjab and Bihar

Fig. 7 (c,d). 'SML 668' at farmer's field in Rajasthan

Table 5. Results of some case studies on summer mungbean production during 2006 in India

Farmer	Area sown	Grain yield (t)	Net return over variable cost (Rs.)
Kartar Singh, Ludhiana	after potato 2 ha after wheat 1.5 ha	3,902.03	103,170 52,357
Baldev Singh, Punjab	after potato 0.8 ha	1.52	42,032
Mehar Singh, Ludhiana	after potato 12 ha after wheat 1 ha	19,681.32	608,112 34,170
Swarn Singh, Sriganganagar	after potato 4 ha	5.00	225,000
Ramesh Godara, Sriganganagar	2 ha solo crop	2.00	40,000

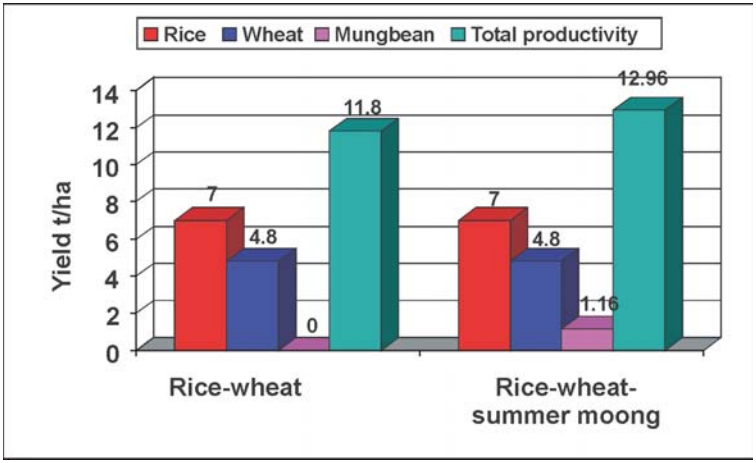

Fig. 8. Productivity of rice-wheat and rice-wheat-summer mungbean cropping system

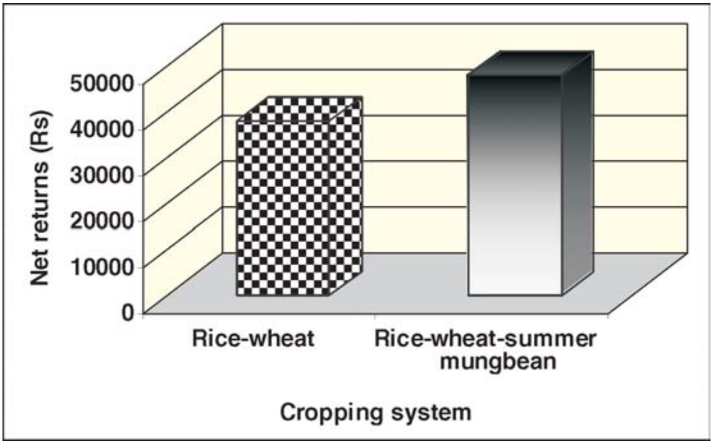

Fig. 9. Economics of rice-wheat and rice-wheat-mungbean cropping system

For *Kharif* season, the average net returns was about Rs. 24,300/ha depending upon market demand and price of mungbean (Grover *et al.*, 2004). The return on variable cost was 90.28%, 38.58%, and 128.20% for mungbean after wheat, potato and *Kharif* season crop, respectively, in Punjab (Grover *et al.*, 2006). The benefit cost ratio of improved mungbean technology in Rajasthan was 2.0 (Siag and Prakash, 2007).

The benefit-cost ratio for the farmers using the improved varieties has been estimated to be around 2.18 in Bangladesh (Afzal *et al.*, 2004). In 2003, a massive adoption of AVRDC mungbean over local cultivars through farmer participatory trials and informal research and development across 13 districts in the low hills and *terai* ecosystems of Nepal has diversified cropping patterns (Khanal, 2004).

6. Seed Production Program

Seed is a key input in increasing productivity of improved varieties, and quality seed alone accounts for at least 10-15% increase in production. Several agencies are producing 'SML 668' seed, the "Seed Village" program was highly successful in Punjab. Bangladesh transferred the Seed Village model to its farmers. At the end of two years, India and Bangladesh were able to produce a total of 45,000 tons of seed, sufficient to cover nearly 1.5 million ha. In addition, participants from Bangladesh, India and Nepal noted the importance of sound crop management practices to obtain the genetic potential of the new varieties and to conserve natural resources. PAU produced 15 tons of seed in summer 2001, which was allotted to different agencies like Punjab State Seed Corporation (PSSC), National Seed Corporation (NSC), and progressive farmers for further multiplication. PSSC and NSC produced 344 and 465 tons seed in *Kharif* and summer 2002, and 5985 and 963 tons seed in *Kharif* and summer 2003, respectively. In case of seed price increases (Rs. 60/kg in 2006), farmers having their own seed could save up to Rs. 2250/ha (Bains *et al.*, 2005, Singh *et al.*, 2007). In 2006, the total seed produced under the project was 2620 tons in Punjab, Rajasthan, Bihar, and Jharkhand (AVRDC, 2006). In India, since 2005, 433 tons seed of 'SML 668' was produced by PAU Ludhiana, 831 tons under the Seed Village program and more than 15,000 tons by farmers. During 2008, Rajasthan State Seed Corporation (RSSC), NSC and the State Farm Cooperation of India produced 92, 54 and 614 tons seed, respectively, which clearly indicates its popularity, adoption rate, and impact. NSC during summer 2009, and RSSC during *Kharif* 2009 produced 200 and 600 tons seeds of 'SML 668.'

7. Improved Nutrition

Apart from the use of mungbean as *dhal*, a number of value-added products are prepared from mungbean and used in South and Southeast Asian countries (Singh and Singh, 1988; Thirumaran and Seralathan 1988; Subramanian and Yang, 1998; APO, 2003; Bains *et al.*, 2003). The transparent mungbean starch noodle is a high value, special delicacy especially in Chinese, Japanese and Korean cultures. Researchers are investigating ways to make use of the protein, which is normally discarded in the starch making process, either as animal feed or for human consumption (Prabhavat, 1991). Mungbean sprouts are consumed throughout China, Japan, Korea, and Southeast Asian countries. These local value-added products provide income generating job opportunities for rural and urban poor. The role of mungbean for enhancing iron intake has been well-researched (Yang and Tsou, 1998).

In Punjab, improved mungbean recipes were demonstrated to farm families in many villages. Mungbean recipe books with 27 recipes for northern and southern Indian dishes were published (Fig. 10) and the iron bioavailability of these dishes was estimated (Table 6) (Amirthaveni and Yang, 1998, Bains *et al.*, 2003). Thousands of farm women and girls were trained to prepare mungbean recipes (Fig. 11). A study conducted by AVRDC found that in Pakistan, the release of new mungbean varieties led to an increase in consumption. The impact of increased micronutrient intake on productivity was estimated using the combined results of food consumption surveys and health and wage information. Mungbean is an important iron source, especially for women (Weinberger, 2003). Feeding trials conducted in South India for

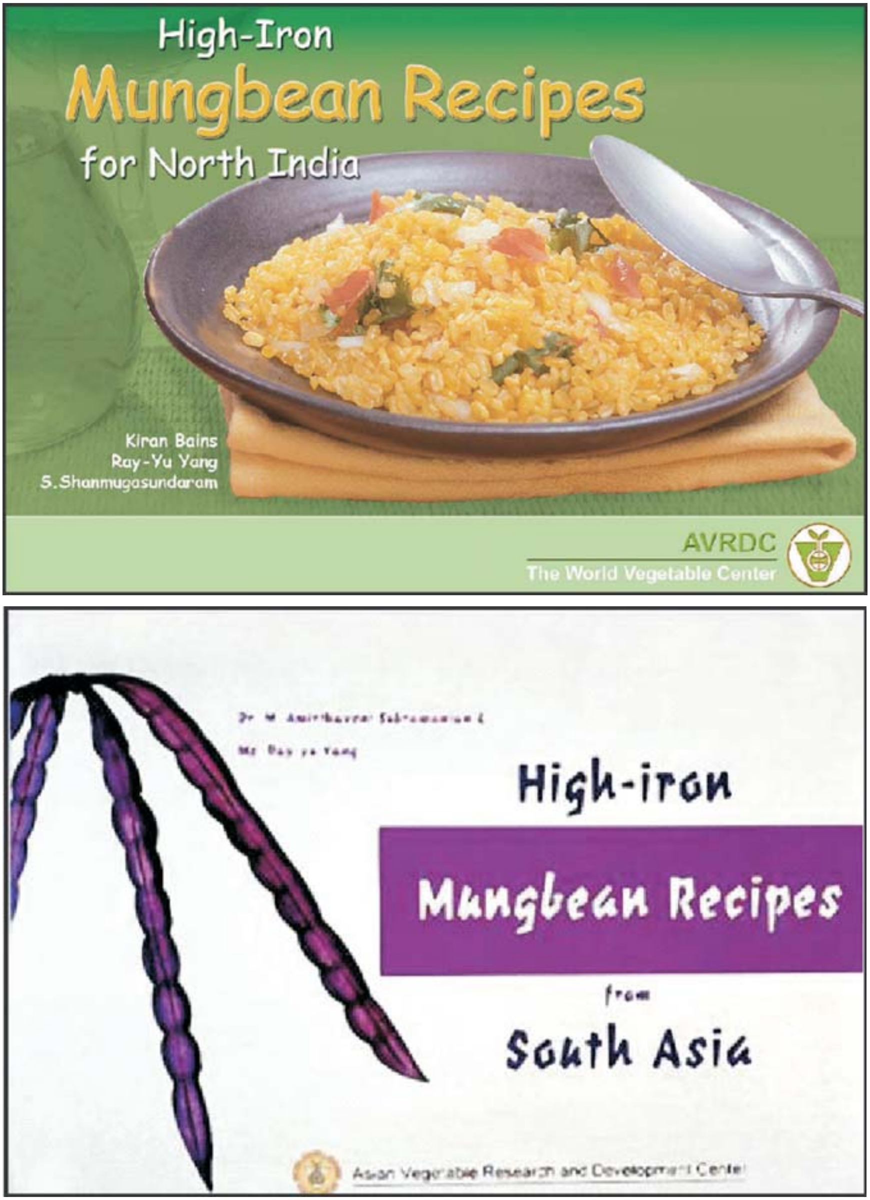

Fig. 10. Mungbean recipe books

one year from October 1999 to October 2000 with 225 school children showed that children receiving supplementation with mungbean dishes high in bioavailable iron (IR1 and IR2) showed greater increase in hemoglobin (on average + 8 g/l) as compared to the group receiving a supplementation with 'traditional' low bioavailability (TR, on average + 3 g/l) and the control group (CG) (Vijayalakshmi *et al.*, 2003).

Table 6. Enhanced iron bioavailability in improved mungbean recipes

Recipes	Bioavailability (%)	Increase (%)
Whole	7.31	-
De-husked	8.00	-
Mung & tomato	15.0	105.19
Mung *namkeen*	12.62	72.64
Parantha	11.32	54.86
Mung spinach *saag*	11.31	54.71
Mung sprouts	10.66	45.83
Dhuli mung *dhal*	10.20	39.53
Mung spinach *pakoras*	9.73	30.10
Dahi bhalla	9.55	30.64
Mung *dhal khichri*	9.16	25.31
Sprout mungbean pulao	8.8	20.66
Whole mung *dhal*	8.14	11.35

Nepalese farmers and their families preferred dishes prepared from improved varieties. Mungbean appears to be a promising commodity for food security and cash flow income of farmers across the entire *terai*, valleys, and low hills of Nepal (Khanal *et al.*, 2004).

Summer mungbean cultivars are better nodulators and are able to fix more nitrogen than local cultivars, require less irrigation, and can be raised without tillage, which helps maintain

Fig. 11. Mungbean recipes: preparation and demonstration programs

soil fertility and texture. Sowing summer mungbean after the wheat harvest increased nitrogen status of soil from 33 to 37 kg/ha (Fig. 12) which saves a 25% nitrogen fertilizer application for the succeeding crop (Sekhon *et al.*, 2007). Incorporation of mungbean biomass (2.2-2.8 t/ha) and the application of 75% nitrogen increases the subsequent paddy crop yield by 4.58 t/ha (Hamid *et al.*, 2004), and summer mungbean sowing saves 60 kg N/ha for rice crop (Rekhi and Meelu, 1983). This system has the potential to increase farm income, improve human health and soil productivity, save irrigation water by preventing farmers from transplanting rice too early, and bolster long-term sustainability of agriculture.

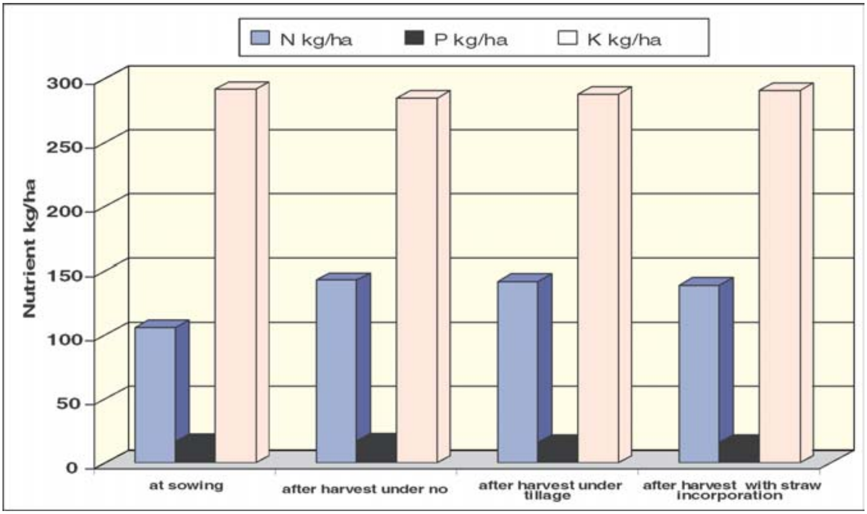

Fig. 12. Soil nutrient status (0-15 cm soil layer) before sowing and after harvesting of summer mungbean

8. Promotional Programs

Since 2005, the Center and its partners in Punjab, Rajasthan, Bihar and Himachal Pradesh have organized more than 20 farmers' field days and 1800 field demonstrations to make the varieties and technologies available to farmers (Fig. 13). More than 5200 farmers and extension specialists have participated in these events.

Fig. 13. Farmers' field days (*contd...*)

Fig. 13. Farmers' field days

9. Conclusion

AVRDC, with the active participation of its partners, focused on increasing sustainability of local farming systems with mungbean. The Center's mungbean team has developed new lines that are being sown across millions of hectares in South Asia, enriching the soil, increasing farmers' incomes, and improving diets in the region. The rapid adoption of improved mungbean is a true transformation; it has created a win-win situation for farmers, traders, consumers - especially the poor - and the environment. Mungbean is a model for the future work of AVRDC, its partners, and farmers. The intervention served as a catalyst to diversify cropping patterns, reduce damage to water and land resources, and make soil more productive. Improved mungbean fits well into the fallow period between rice-rice, rice-wheat, rice-potato-wheat, maize-wheat, cotton, and other cash crops. The area under mungbean cultivation has increased by more than 3 million ha in cereal grain production areas of South Asia. The significant impact of improved mungbean technologies can be shown through the rapid adoption of improved varieties by farmers, and the increase in area and production. In only 60-65 days, farmers can earn Rs. 25,000-30,000 (US$ 550-650), and gain 33-37 kg/ha nitrogen in the soil. Mungbean does not require much water or tillage. In South Asia during the summer season, short duration mungbean has become a favorite crop among farmers. An overwhelming response for cultivation and utilization of this crop was observed among farmers, especially in India, Bangladesh, Pakistan, Nepal and Sri Lanka. Mungbean has improved incomes and livelihoods, and enhanced and improved consumer health through balanced nutrition. When added to a cereal crop rotation, mungbean improves the productivity of nutrient-depleted soils, and improves yields of cereals. With continued investment and promotion, mungbean can continue to alleviate protein and energy malnutrition, raise farmer incomes, and sustain soil fertility in South Asia.

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