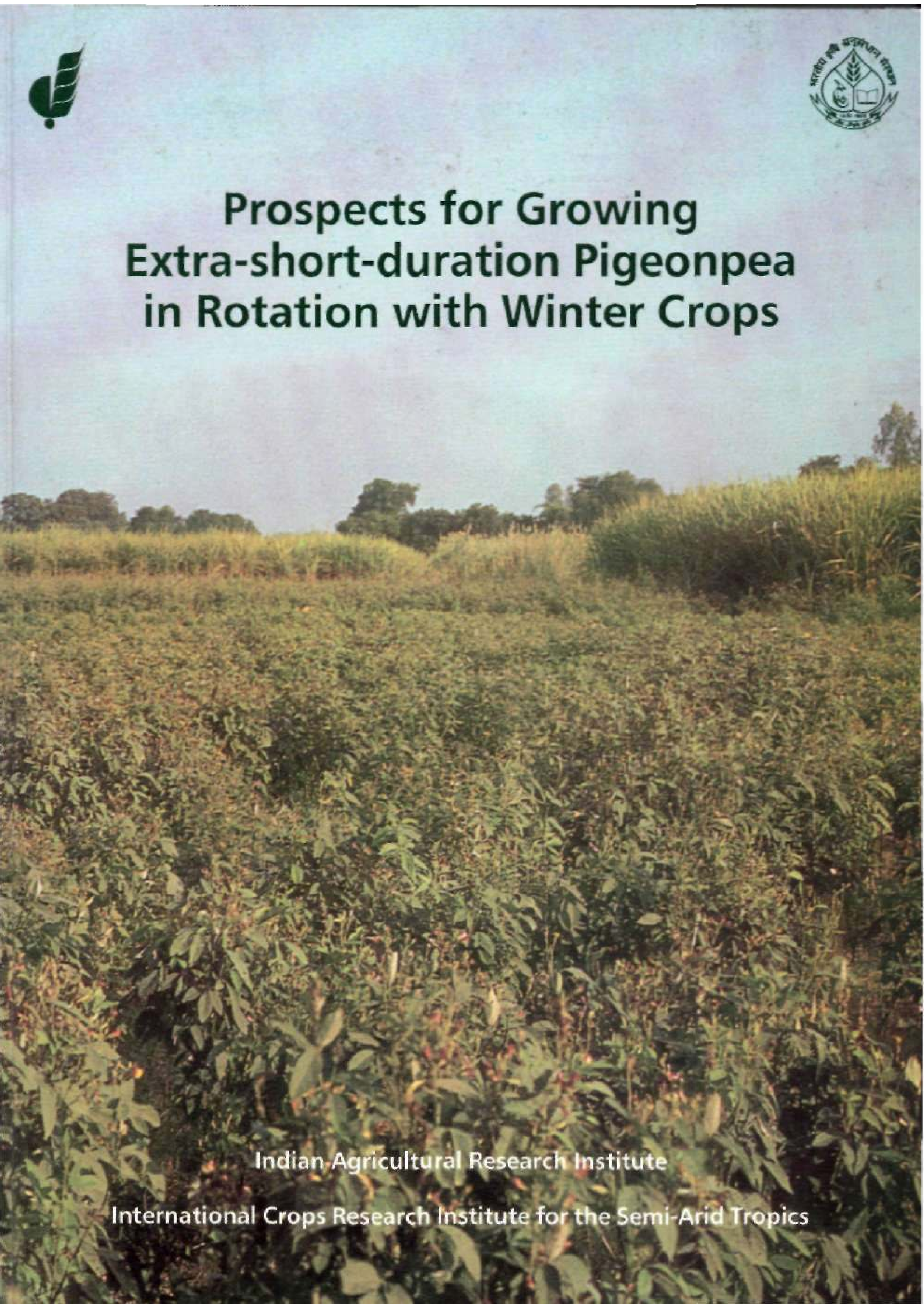
Prospects for Growing Extra-short-duration Pigeonpea in Rotation with Winter Crops



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Abstract

Short-duration pigeonpea varieties have helped establish a new pigeonpea-wheat cropping system in the northwestern plains of India. However, because wheat sowing is often delayed in this rotation, extra-short-duration genotypes that will mature 10-15 days earlier than short-duration ones are being developed. To consider the prospects for their adoption, the Indian Agricultural Research Institute and the International Crops Research Institute for the Semi-Arid Tropics jointly hosted a workshop in New Delhi, India. Participants from Bangladesh, India, Nepal, Pakistan, and Sri Lanka reviewed the status of pigeonpea in cropping systems of the region and discussed four broad areas in relation to extra-short-duration pigeonpea: improving plant type; improving management; extension and demonstrations; and cropping systems, seed production, and socioeconomic issues. The workshop was followed by a monitoring tour of on-farm trials of the new genotypes (mainly ICPL 85010) in nearby districts of Uttar Pradesh and Haryana.

Prospects for Growing Extra-short-duration Pigeonpea in Rotation with Winter Crops

Proceedings of the
Workshop and Monitoring Tour
16-18 Oct 1995
Indian Agricultural Research Institute
New Delhi, India

Edited by

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1996

Objectives

- To assess status of extra-short-duration (ESD) pigeonpea as an actual and potential crop type in the Indo-Gangetic plains region.
- To examine farmers' field plots of ESD pigeonpea in comparison with standard short-duration pigeonepa genotypes grown in the region.
- To discuss and prioritize constraints to production and adoption of ESD pigeonpea.
- To develop a coordinated research and development program for ESD pigeonpea in this region.

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Preface

With the availability of short-duration (SD) varieties of pigeonpea, cultivation of this crop in rotation with wheat became feasible in the Indo-Gangetic plains zone of South Asia. While this system has established itself, there is concern about the lateness of the varieties commonly used, such as UPAS 120, Manak, and T 21, which delays the sowing of wheat beyond the optimal time (around mid-November).

Extra-short-duration (ESD) pigeonpea genotypes, which mature 10-15 days earlier than SD ones, would thus fit better into pigeonpea-wheat rotations. To assess the best way to proceed in research and development, the Indian Agricultural Research Institute (IARI) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) jointly hosted a workshop and monitoring tour on Prospects for Growing Extra-Short-Duration Pigeonpea in Rotation with Winter Crops at the IARI, New Delhi campus, 16-18 Oct 1995. The Workshop was inaugurated by Dr R S Paroda, Director General, Indian Council of Agricultural Research (ICAR). The inaugural session was chaired by Dr V L Chopra, Emeritus Scientist, and the delegates were welcomed by Dr R B Singh, Director, IARI. Closing remarks were given by Dr R B Singh, and Dr D E Byth, Associate Director General (Research), ICRISAT. Representatives from the national agricultural research systems of Bangladesh, India, Nepal, and Sri Lanka joined ICRISAT and IARI scientists in the deliberations.

The Workshop was combined with a monitoring tour to observe a series of on-farm evaluations of ESD pigeonpea genotypes (mainly ICPL 85010) in comparison with standard SD varieties, such as UPAS 120 and Manak, in the neighboring districts of Ghaziabad (Uttar Pradesh) and Sonepat (Haryana). The trials were conducted as a joint activity of the Pigeonpea Project and Integrated Systems Project No. 4 of ICRISAT, IARI, and the Krishi Vigyan Kendras of CCS Haryana Agricultural University and G B Pant University.

This report summarizes the proceedings of the Workshop. Included in it are status reports from the participating countries and papers presented by the scientists of ICRISAT, IARI, and several state agricultural universities of India. Four working groups considered the following topics and suggested areas for future collaborative activities:

- I Improving plant types in ESD pigeonpea
- II Improving management
- III Extension and demonstrations
- IV Cropping systems, seed production, and socioeconomic issues.

We hope this report will serve as a working document on which to base future research and development on ESD pigeonpea to make it a viable component of cropping systems in the subtropics.

- The Editors

The Development of and Adoption Prospects for Extra-short-duration Pigeonpea

Laxman Singh[1]

Introduction

This paper considers the prospects for adoption of extra-short-duration (ESD) pigeonpea, *Cajanus cajan* (L.) Millsp., in the irrigated wheat cropping systems of the northwestern and north-central alluvial Indo-Gangetic plains of India. A brief historical background of the development of short-duration (SD) and ESD pigeonpea is given to place the issue in perspective.

Development of Short- and Extra-short-duration Pigeonpea

Globally, pigeonpea cropping systems have developed around medium-duration (MD) and long-duration (LD) cultivars to meet domestic food, fodder, and fuelwood needs. Rainfed farming systems are also intensified by intercropping these cultivars with short-season cereals (maize, sorghum, pearl millet) and a variety of other crops. These traditional systems still predominate in all the major pigeonpea-growing regions of the world. However, MD and LD cultivars do not fit into the intensive wheat-based systems that became important after the green revolution in the 1960s. This necessitated development of cultivars that would mature before the optimum time for wheat sowing. Such cultivars were also expected to escape frost, the major yield-reducer for LD pigeonpea in some subtropical environments.

A first step towards the development of SD genotypes was the identification of T 21 (from a cross, T 1 x T 190) in 1961 in the state of Uttar Pradesh, India, for double-cropping in irrigated wheat systems in the north-central alluvial plains. T 21 was subsequently identified for the entire country in 1973 (AICPIP 1986) for a wide range of cropping systems, including monocropping in rainfed areas and intercropping with short-season grain legumes, such as mung bean. T 21 has spread from central Uttar Pradesh to the alluvial plains in western Uttar Pradesh and the states of

1. ICRISAT Asia Center, Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 1084.

Laxman Singh. 1996. The development of and adoption prospects for extra-short-duration pigeonpea. Pages 1-5 *in* Prospects for growing extra-short-duration pigeonpea in rotation with winter crops: proceedings of the IARI/ICRISAT Workshop and Monitoring Tour, 16-18 Oct 1995, New Delhi, India (Laxman Singh, Chauhan, Y.S., Johansen, C, and Singh, S.P., eds.). New Delhi 110 012 and Patancheru 502 324, Andhra Pradesh, India: Indian Agricultural Research Institute and International Crops Research Institute for the Semi-Arid Tropics.

Haryana and Punjab and elsewhere. However, its phenology did not adequately meet the need for double-cropping, as it delayed wheat sowing beyond the optimum time (usually mid-November). Therefore, farmers adopted early (April-May) sowing of T 21 with irrigation, to advance its harvesting time and allow timely sowing of wheat. However, with April-May irrigated sowing, T 21 produces excessive biomass (20 t ha^{-1}), resulting in a low harvest index of < 10%. As the crop grows 3-4 m tall, it is not feasible to use insecticidal sprays where needed.

Because of these drawbacks of T 21, efforts were made to develop genotypes of shorter duration. In the mid-1970s, three of these, UPAS 120 (SD), Prabhat, and Pant A 3 (ESD), were identified and released (AICPIP 1986). These have since been used as controls in multilocation trials of ESD and SD varieties developed by the All India Coordinated Pulses Improvement Project (AICPIP) of the Indian Council of Agricultural Research (ICAR). Several new SD and ESD varieties were tested in these trials and released in the 1980s: Pusa Ageti (S 5), AL 15, AL 201, Pusa 33 (Ramanujam), Pusa 84, Manak, Paras, and ICPL 151 (Jagriti) for the north-west plain zone (NWPZ) and the central zone (CZ) and Co 1, Co 2, Co 3, Co 4, Hy 2, Hy 4, TT 6, TT 10, and ICPL 87 for the CZ and peninsular India. Hybrids ICPH 8, Co H 1, and PPH 4 have been released during the last 5 years.

However, some confusion continued in the usage of nomenclature and the classification of SD and ESD pigeonpea. Gupta et al. (1989), therefore, suggested a uniform nomenclature/classification for SD and ESD pigeonpea, based on the phenology data from two sites in India, ICRISAT Asia Center (17° N) and Hisar (29° N), and related them to the classification of the AICPIP and Green et al. (1979). Accordingly, ESD includes the Prabhat and Pant A 3 group, which normally matures in < 115 days at Hisar and <110 days at ICRISAT Asia Center. The SD-A or UPAS 120 group (includes ICPL 151 and also includes ICPL 87, which matures 1 week later than ICPL 151) matures in an average of 130 days at Hisar and 115 days at ICRISAT Asia Center; the SD-B or T 21 group matures in an average of 140 days at Hisar and 125 days at ICRISAT Asia Center.

Cultivars of determinate and indeterminate plant types have been developed in both ESD and SD pigeonpea; for example, in the ESD group, ICPL 84023 and Prabhat are determinate and ICPL 87111 is indeterminate. In the SD-A group, ICPL 151 and ICPL 87 are determinate and UPAS 120 is indeterminate; in the SD-B group, ICPL 83024 is determinate and T 21 is indeterminate.

Determinate plant types generally have a short flowering period; the canopy is flat-topped, and the apical buds of the main shoots develop into inflorescences. Indeterminate plant types have a relatively long flowering period; apical buds remain vegetative, and flowers occur in axillary racemes spread over considerable lengths of the stem. The indeterminate types tend to be taller and, it is generally believed, suffer less from pod- and flower-damaging insect pests than determinate types. Gupta et al. (1991), after analyzing several years' data from trials of both types of SD pigeonpea at Hisar, concluded that under insecticidal protection, determinate types had mean yields of 3.0 t ha^{-1} and indeterminate types, 2.9 t ha^{-1}. Under unprotected conditions, however, determinate types yielded 1.1 t ha^{-1} and indeterminate types, 1.4 t ha^{-1}.

Thus, although determinate types were marginally more productive under protected conditions, indeterminate types were superior under unprotected conditions.

Because the indeterminate types are so tall, insecticidal spraying is difficult and not very effective. Therefore, determinate ESD types may have the best adoption potential for double-cropping in- the high-input, irrigated rice-wheat system in the NWPZ.

Several ESD types suited to different regions have been identified. ICRISAT shared the enhanced germplasm of ESD pigeonpea for on-farm and on-station testing in the NWPZ (ICPL 85010 and ICPL 88009, among others). In 1995, Andhra Pradesh Agricultural University released ICPL 84031 (Durga) for the northern Telangana region of Andhra Pradesh (SZ). Himachal Pradesh Agricultural University has identified ICPL 85010 for double-cropping with wheat in the plains areas of that state.

Outside India, the University of Queensland (Australia) released the ESD types Quantum and Quest, and the University of Minnesota (USA) released MN 1, MN 5, and MN 8.

The following genotypes with a good agronomic background and resistance to diseases and abiotic stresses have been identified at ICRISAT.

Pigeonpea genotype	Resistance
ICPL 90002, ICPL 90011	Sterility mosaic disease (SMD)
ICPL 89020, ICPL 88003	Fusarium wilt and SMD
ICPL 84023	Phytophthora blight (PB) and waterlogging
ICPL 88039, ICPL 84023	Drought

Waterlogging predisposes the plant to phytophthora blight, which commonly occurs in the NWPZ during the rainy season. Stable resistance for this disease is being introgressed from the tertiary gene pool (*Cajanus platycarpus)* through embryo rescue and tissue culture techniques.

Adoption

Status

Adoption of ESD and SD pigeonpea (UPAS 120, T 21, Manak, Paras, AL 15, AL 201) in the NWPZ has increased steadily during the last two decades. It is estimated that over 100 000 ha are grown in Punjab, Haryana, and western Uttar Pradesh. Further adoption can be catalyzed with enhanced germplasm and better management of stresses that reduce the stability and productivity of ESD pigeonpea.

Constraints

Instability of production at a location over seasons and varying performance over locations are constraints to the adoption of ESD pigeonpea (Chauhan et al., these Proceedings). The major biotic and abiotic factors responsible for instability and reduced productivity in the NWPZ are insect pests *(Maruca testulalis, Helicoverpa armigera,* and *Melanagromyza* sp), diseases (PB and SMD), waterlogging, intermittent drought, and soil salinity.

Also hampering the adoption and spread of improved germplasm and technology are the weak linkages among research scientists, extension workers, and seed agencies. On-farm adaptive research as a method of stimulating adoption should therefore form an integral component of genetic enhancement research for SD and ESD pigeonpea. These are new crop/plant types, subject to kinds and degrees of biotic and abiotic stresses and requiring production and management practices very different from those used for traditional MD and LD pigeonpea cultivars.

There is also a need to focus attention on grain quality parameters of SD and ESD pigeonpea. Grain quality is adversely affected when maturity coincides with rainy and cloudy weather, which increases percent hard-seededness and spoilage by molds. Time of sowing also influences seed set in SD and ESD pigeonpea, because of the effects of temperature and rainfall. Good pod development but early abortion of growing seed have been observed in May-sown T 21 at Kanpur in northern India and ICPL 85010 at Warangal in peninsular India. This phenomenon has not been researched, and it continues to hamper adoption.

Nonavailability of good quality seed of improved germplasm continues to be mentioned as one of the constraints to the spread of adoption (Jain and Chauhan, these Proceedings).

Opportunities for Genetic Enhancement and Adoption

Multidisciplinary cooperative research is needed for genetic enhancement of ESD for target production systems. Current research needs strengthening in the following areas:

- Broadening of the genetic base for stability and productivity by introgression of secondary and tertiary gene pool; stability includes tolerance of the relevant biotic and abiotic stresses.
- Studies on appropriate plant type, including rapid early growth, yield stability, and optimum harvest index.
- Development of hybrid pigeonpeas.
- Studies on seed and pod set and tolerance of damage by rains at maturity.
- On-farm research to analyze constraints to adoption of ESD pigeonpea.
- Seed production and quality control.

The outcome of the program should be measurable in terms of a better understanding of the ESD plant type and expanded adoption of this crop to cover 0.5

million hectares in the NWPZ, which would increase production by 0.7-1.0 million tons by the year 2005.

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Extra-short-duration Pigeonpea in India: Research in the All India Coordinated Pulses Improvement Project

A N Asthana, Masood Ali, and S D Dubey[1]

Introduction

Pigeonpea is the second most important grain legume in India, which produces 91% of the world's total (FAO 1991). It is grown throughout the country, except in frost-prone areas and at high altitudes; however, the largest area lies in the semi-arid tracts in the states of Maharashtra, Karnataka, Uttar Pradesh, Madhya Pradesh, Gujarat, Andhra Pradesh, Orissa, Tamil Nadu, and Bihar (Table 1).

Table 1. Area and production of pigeonpea in India, 1980/81 and 1991/92.

	Area ('000 ha)		Production ('000 t)	
State	1980/81	1991/92	1980/81	1991/92
Andhra Pradesh	247.6	338.2	60.3	124.4
Bihar	93.7	66.0	91.0	91.0
Gujarat	228.2	397.0	180.3	239.7
Haryana	7.8	51.8	3.7	53.0
Karnataka	340.6	530.7	194.0	175.7
Madhya Pradesh	533.6	451.9	497.1	345.7
Maharashtra	705.5	1016.1	537.1	362.2
Orissa	10.3	167.6	52.1	111.0
Punjab	11.6	12.9	9.5	12.8
Rajasthan	31.0	22.2	11.5	5.5
Tamil Nadu	124.6	131.4	50.9	95.4
Uttar Pradesh	515.6	521.6	632.4	559.6
West Bengal	27.2	5.8	21.2	2.9
Other	14.3	13.5	6.6	10.0
Total	2891.6	3726.7	2347.7	2088.9

Source: Agricultural Situation in India (various years).

1. Indian Institute of Pulses Research, Kanpur 208 024, Uttar Pradesh, India.

Asthana, A.N., Masood Ali, and Dubey, S.D. 1996. Extra-short-duration pigeonpea in India: research in the All India Coordinated Pulses Improvement Project. Pages 6-10 *in* Prospects for growing extra-short-duration pigeonpea in rotation with winter crops: proceedings of the IARI/ICRISAT Workshop and Monitoring Tour, 16-18 Oct 1995, New Delhi, India (Laxman Singh, Chauhan, Y.S., Johansen, C., and Singh, S.P., eds). New Delhi 110 012 and Patancheru 502 324, Andhra Pradesh, India: Indian Agricultural Research Institute and International Crops Research Institute for the Semi-Arid Tropics.

Traditionally, pigeonpea is grown as a rainfed crop, usually mixed or intercropped with cereals (e.g., sorghum, maize, pearl millet, rice), legumes (e.g., groundnut, soybean, urd bean, mung bean, cowpea), or commercial crops (e.g., cotton, castor). The genotypes used are generally indeterminate, tall, and of medium to long duration. The system is primarily oriented to subsistence and multiple crop production and accounts for over 90% of the pigeonpea production.

In recent years, development of short-duration (SD) pigeonpea genotypes (<150 days) has led to a dramatic shift in the irrigated areas of northern India, where a pigeonpea-wheat crop rotation is gaining considerable importance. However, the unstable production of pigeonpea due to biotic and abiotic stresses, and the tough competition offered by upland crops such as maize, cotton, groundnut, and soybean may slow down the pace of its expansion, unless high-yielding genotypes (2 t grain ha^{-1}) of shorter duration (110-140 days), with resistance to major diseases and pests, are developed to fit into various production systems.

Historical Developments

In India, systematic research on pigeonpea improvement began in 1966, with the commissioning of an All India Coordinated Pulses Improvement Project, with its headquarters in Delhi. Initially, only one trial on genotypic evaluation was started, but it was soon evident that the wide range in duration of the available genotypes prevents a valid comparison of their production potential. Consequently, in 1968/69, three sets of trials, based on duration-short (<160 days), medium (160-200 days), and long (>200 days)-were developed. As a result of this, the first SD pigeonpea, T 21 (160 days), was developed and released for cultivation in Uttar Pradesh. Subsequently, it spread to other states, such as Madhya Pradesh and Maharashtra, especially under irrigation. However, the sowing of wheat was often delayed after T 21 pigeonpea. Efforts continued to develop genotypes of shorter duration (140-150 days) than T 21, to fit into the wheat-based cropping systems of northern India. In the early 1970s, 120- to 140-day genotypes, Pant A 3 and Prabhat, were developed, but because of their low yields and susceptibility to several biotic and abiotic stresses, they were not accepted by farmers. Nevertheless, these genotypes were widely used as parents for developing high-yielding SD genotypes.

In 1976/77, UPAS 120 (130-140 days) was developed-a landmark in the pigeonpea improvement program. Later, others, such as AL 15, Manak, Sagar, Pusa 33, ICPL 87, ICPL 151, and Pusa 84, were developed and released for cultivation in different agroclimatic zones.

Work on an extra-early group (100- to 120-day duration) was launched in 1982/83, in the background of Prabhat (determinate) and Pant A 3 (semideterminate) genotypes. The main consideration in developing extra-short-duration (ESD) genotypes was to ensure timely sowing of wheat and look for other intensive cropping systems into which pigeonpea could easily fit. Because of the considerable variation in the duration of these genotypes in different agroecological zones, the maturity period for entering genotypes in the Early Arhar Coordinated Trial (EACT) and the Extra-early Arhar Coordinated Trial (EXACT) trial was fixed as follows:

	EACT	EXACT
North-west plain zone (NWPZ)	120-135	<120
Central zone (CZ)	112-125	<112
Southern zone (SZ)	100-110	<100

Present Status of Research

Multilocation trials were launched in the NWPZ, CZ, and SZ concurrently, with UPAS 120 and Prabhat as controls. The primary goal of developing ESD pigeonpea was to sustain the pigeonpea-wheat system, as delayed sowing of SD genotypes or a prolonged rainy season often prevented timely sowing of wheat. However, the duration of the entries contributed to the EXACT program was almost at par with the EACT control, UPAS 120, and their yields were also not encouraging (Table 2).

Table 2. Yield (t ha^{1}) and duration (days) of extra-early pigeonpea genotypes in the EXACT[1] trials under the All India Coordinated Varietal Trials for pigeonpea.

	NWPZ[2]		CZ[2]		SZ[2]	
Year	Yield	Duration	Yield	Duration	Yield	Duration
1983	1.0-2.1	149-168	0.8-1.3	116-121	1.3-2.3	106-122
1984	1.8-2.2	133-145	1.0-1.7	99-125	0.6-0.8	92-107
1985	1.6-2.5	120-167	1.0-1.9	103-125	0.8-1.6	111-123
1986	1.3-2.1	114-132	0.8-1.2	110-117	0.8-0.9	98-120
1987	1.5-2.2	132-155	0.6-1.1	111-136	0.8-1.1	92-118
1988	1.1-1.4	117-142	0.7-1.2	108-117	0.8-2.0	96-108
1989	1.4-2.0	123-134	0.6-1.2	118-128	1.3-2.0	102-114
1990	1.6-2.0	135-141	0.9-1.3	114-122	0.6-1.0	106-117
1992	0.9-1.6	139-154	1.1-1.5	132-145	1.3-2.0	88-105
1993	1.3-1.8	140-153	-	-	-	-

1. **EXACT** = Extra-early Arhar Coordinated Trials.
2. **NWPZ** = north-west plain zone; CZ = central zone; SZ = southern zone.

***Source**:* Data compiled by Project Coordinator, AICPIP.

In the NWPZ, none of the entries matured within 120 days; AF 98, ICPL 85010, and ICPL 88001 matured in 135-136 days as against UPAS 120 (147 days), but their grain yields were lower than the yield of the control. In 1993/94, although TAT 140 showed a distinct yield advantage over UPAS 120, it did not qualify as ESD.

In the CZ and SZ, the program continued only until 1990/91. The duration of the test entries was either at par with UPAS 120 or longer, and only the highest-yielding test entry gave yields comparable to the control.

The Research Base

The Indian Institute of Pulses Research (IIPR), under the control of the Indian Council of Agricultural Research, is the nodal center for the organization of a research program on pulse crops in the country. It operates through three All India Coordinated Projects: one each on pigeonpea, chickpea, and MULLARP (mung bean, urd, lentil, lathyrus or grasspea, rajmash or kidney bean, and peas). The national network on pigeonpea is spread over 11 states, with 17 centers besides the coordinated centers. Several voluntary centers also undertake testing programs. The basic research is mainly carried out at the headquarters in Kanpur, Uttar Pradesh.

Constraints to ESD pigeonpea development

Despite 12 years of research, no ESD variety could be identified for release. Some of the major constraints to progress in this direction are as follows:

- Breeding materials of ESD types are not available.
- Most of the ESD lines are poor yielders.
- ESD lines are generally determinate, with cluster podding, which favors incidence of insect pests, such as *Maruca testulalis* and *Helicoverpa armigera.*
- ESD lines, by and large, are highly susceptible to the major pigeonpea diseases, phytophthora stem blight and sterility mosaic.
- ESD lines are generally susceptible to both waterlogging and drought.
- Currently available ESD breeding materials give poor biomass and stick yields, which are an important economic consideration in pigeonpea cultivation.

Prospects for ESD pigeonpea development

In the last decade, pigeonpea cultivation has grown significantly, especially in the states of Andhra Pradesh, Gujarat, Haryana, Karnataka, and Maharashtra (Table 1). This is largely due to the introduction of SD genotypes in new cropping systems. Cultivation of pigeonpea in the NWPZ (Haryana, Punjab, Delhi, and Uttar Pradesh) began only with the development of SD cultivars. At present, all genotypes grown in this region are short-duration.

Extra-short-duration genotypes of pigeonpea, maturing in 110-130 days, with a yield potential of 1.5-2.0 t ha^{-1} and possessing resistance to the major diseases, may bring under pigeonpea about an additional 0.8 million hectares in the irrigated wheat belt of the NWPZ and another 0.2 million hectares in the rainfed coastal peninsula with bimodal rainfall.

Appropriate plant protection measures will have to be taken to control major pests.

Future Research Needs

Future research on SD and ESD pigeonpea will need to focus on the following areas:

- Developing semideterminate and input-responsive cultivars with yield potential of 1.5-2.0 t ha^{-1} and adequate dry stick yield.
- Incorporating resistance to major diseases-phytophthora stem blight, SMD, and wilt.
- Developing an integrated pest management (IPM) system to control key pests-*M. testulalis, Eucosma critica,* and *H. armigera.*
- Developing cultivars with a wide range of adaptability to stresses, as presently available early-maturing genotypes are generally susceptible to abiotic stresses, such as excess moisture and drought.
- Working out agronomic optima for realizing the yield potential of ESD pigeonpea under a range of agroecological conditions.
- Developing new, intensive cropping systems that can fit in ESD pigeonpea as one component.

Extra-short-duration Pigeonpea in Haryana

Y S Tomer and Ram Dhari[1]

Pigeonpea is a comparatively recent introduction in Haryana (except in Gurgaon and Ambala districts). However, it has become the second most important pulse crop in the state, after chickpea, as evidenced by the dramatic increase in area, from 2200 ha in 1976 to around 50 000 ha in 1993/94. This expansion resulted directly from the introduction in the mid-1970s of short-duration (SD) varieties (130-160 days), such as T 21, UPAS 120, and Prabhat, which could be accomodated in intensive cropping systems.

The pigeonpea-wheat rotation became possible under a double-cropping system that is gaining further importance in the states of Haryana, Punjab, and Rajasthan, and in western Uttar Pradesh.

The major reasons for the popularity of pigeonpea in such new areas are the attractive returns, ease of cultivation with limited inputs, and good and stable yield potential compared with other pulse crops; additionally, pigeonpea stems and biomass also make a good source of fuel in the rural areas.

Objectives of the Pigeonpea Research Program in Haryana

Recognizing the importance of the crop, Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar, initiated a research program on pigeonpea to

- develop early- and extra-early-maturing varieties for timely (June) and late (July) sowing;
- formulate appropriate crop production technology for such varieties;
- develop effective and efficient plant protection measures;
- identify efficient *Rhizobium* strains and demonstrate their inoculation in farmers' fields;
- transfer technology to farmers.

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The Research Program

Pigeonpea breeding

Breeding for short duration. For intensively cropped agricultural areas, such as Haryana, Punjab, and western Uttar Pradesh, where most of the required inputs are readily available and productivity is much higher than in dry areas, only extra-short-duration (ESD) and SD pigeonpea varieties that can be fitted into, the pigeonpea-wheat rotation are suitable. Our efforts are therefore concentrated on developing and introducing varieties of different durations, so as to account for the entire sowing period, from mid-April to mid-July. Short-duration, medium-short-duration and extra-short-duration varieties are required for early, midseason, and late-season sowing.

All such varieties tend to mature at more or less the same time. Therefore, breeding efforts are under way to develop high-yielding SD and ESD varieties, mainly by reducing the vegetative phase. In the early 1970s, germplasm was collected from different sources and systematically evaluated to identify promising genotypes for testing in the state. Three varieties introduced from Uttar Pradesh—Prabhat, UPAS 120, and T 21—were found suitable and released in the mid-1970s for general cultivation in Haryana.

A hybridization program was also initiated, to create variability. As artificial crossing is a tedious and time-consuming process, with only limited chances of success, careful selection of suitable parents is a prerequisite for a hybridization program. Accordingly, about 400 germplasm lines were evaluated, and suitable parents identified, mostly from early-maturing sources (Table 1).

A large number of crosses (single, double, three-way, and multiple) were made. The segregating generations are advanced through single-plant selection (pedigree method), bulk selection, and single-seed descent techniques. The cross UPAS 120 x T 21 yielded the early-maturing variety released as Manak in 1985. Its mean yield over locations and years (1.96 t ha^{-1}) is higher than that of UPAS 120 (1.73 t ha^{-1}).

Table 1. Parents suitable for pigeonpea hybridization.

Character	Most promising donors
Early flowering and maturity	AL 574, AL 586, Bagola 2, EE 76, H 88-23, H 88-24, H 88-25, ICPL 312, ICPL 83002, ICPL 83018, ICPL 84023, ICPL 85024, Prabhat, T 21, UPAS 120
Dwarf stature	AL 259, AL 265, ICPL 312, ICPL 85024, ICPL 85059
Good branching	ICPL 289-31, ICPL 84082, Fazalpur 10, 83 H 15-28, 83 H 17-12, 85 HP 3047-2
Bold seed	ICPL 151, ICPL 279, ICPL 83006, H 79-42, H 82-124

Manak was well received by Haryana farmers. As it matures 8 days earlier than UPAS 120, Manak enables farmers to sow a succeeding wheat crop on time, even if the pigeonpea is sown as late as mid-July. Consequently, the area under pigeonpea has expanded considerably, especially in the canal command areas.

Another early-maturing variety, H 82-1 (Paras), was also developed from a single cross, EE 76 x UPAS 120, following the pedigree selection method. This variety was identified for the north-west plain zone (NWPZ) and is likely to be released at the national level.

For the pigeonpea-wheat rotation, currently available pigeonpea varieties have to be sown in June, otherwise the crop matures late, delaying wheat sowing and causing considerable yield loss. Therefore, even earlier-maturing types than Manak have been developed to enable sowing even in late July. Table 2 shows the performance of some promising genotypes.

Table 2. Performance[1] of extra-short-duration (ESD) pigeonpea genotypes sown 15-28 July in Haryana, India, 1986-90.

Genotype	Yield ($t\ ha^{-1}$)	Duration (days)	Height (cm)
H 81-22	1.8	120	157
H82-1	1.6	117	147
UPAS 120 (control)[2]	1.3	126	153
Prabhat (control)	1.2	115	125
Manak (control)	1.4	122	153

1. Means of 5 years.
2. Mean of 3 years.

Averaged over 5 years, genotype H 81-22 gave the highest yield, followed by H 82-1. These genotypes were sown in the second half of July and harvested by the end of November; thus wheat could be sown in the first 2 weeks of December. Because the plants do not grow tall, plant protection measures, such as insecticide spraying, can be easily adopted. The growing of such cultivars is likely to allow raising of a third crop (cowpea or any other fast-growing fodder crop) during the interval between the wheat harvest (mid-April) and the sowing of the ESD pigeonpea variety (mid-July or late July).

Breeding for dwarf stature. Pigeonpea normally grows about 3 m tall, which hampers insecticide spraying for the control of pod borer *(Heliothis armigera)* and podfly *(Melanagromyza* sp). This drawback could be overcome by breeding dwarf plant types that would make spraying practically feasible.

Sources of dwarfing genes (D_o, D_1 and D_2) are available. However, only the D_0 (ICPL 85059) source was used for breeding dwarf genotypes in our program. Except for its dwarf stature, this line has few agronomically desirable characters. Its compact, bushy plants have brittle stems; it is quite late-flowering and bears only a few pods with small seed.

The dwarfism is governed by two duplicate genes, which segregate in a ratio of 15 tall:I dwarf in tall x dwarf crosses. No desirable segregants were found in segregating generations, because of undesirable associations, and most segregants were generally parental types. Breeding of genetically dwarf types, removing undesirable associations, is a long process, and efforts in this direction need be continued.

Agronomy

Agronomic research on pigeonpea relates to sowing time and method, fertilizer and weed management, and intercropping systems.

Sowing date. Sowing dates were found quite critical for obtaining good and economic grain yield of pigeonpea. T 21 was the best variety for early sowing (March-May), being the highest yielder. UPAS 120 and Manak were found suitable for sowing from the end of May into June. These sowings produced significantly higher grain yields than crops sown in the first week of July. Mid-July sowing further reduced yields, which were 40-50 kg day^{-1} ha^{-1} lower than yields of a crop sown on 15 June.

Weed management. In the early stages of crop growth, weeds cause the maximum yield loss. Hand weeding once or twice was found superior to chemical weed control. Of the weedicides we tested, pendimethalin @ 1.00 kg ai ha^{-1} (preemergence) controlled weeds most effectively, resulting in higher pigeonpea grain yields than other weedicides.

Fertilizer. For maximum grain yield, application of 20 kg N and 50 kg P_2O_5 ha^{-1} has been recommended. Application of zinc and sulfur (as $ZnSO_4$ 25 kg ha^{-1}) further improved yield.

Intercropping. During the *kharif* (rainy) season, short-duration varieties of cowpea, mung bean, or urd can be successfully grown as an intercrop in normal stands of SD and ESD pigeonpea varieties, without reducing the grain yield of pigeonpea. For this purpose, one row of an intercrop between two rows of pigeonpea 50 cm apart can be accommodated. In spring/summer (March to mid-April), two rows of cowpea, mung bean, or urd can be raised between two rows of pigeonpea sown 75 cm apart. This system yielded 0.7-1.0 t ha^{-1} grain of mung bean or urd, or 2.0-2.5 t ha^{-1} of green fodder for cattle during the dry season when fodder is scarce. Thus, intercropped pigeonpea was found more remunerative than sole-cropped pigeonpea. However, the whole package of practices for intercrops should be followed for this system to be successful.

Entomology

The major pests of pigeonpea in Haryana are jassids, thrips, green stinkbug, blue butterfly, pod borer, and podfly. The available germplasm and elite genotypes were screened against pod borer and podfly, but none showed adequately high levels of resistance. However, some lines were comparatively less susceptible than others: AF 40, AL 7, ICPL 909, MTH 14, PDE 45-2, Sehore 197, and TAT 10 to pod borer; AL 134, H 84-10, and P 851 to podfly; and AL 1, H 82-1, MTH 10, and TAT 10 to both pests.

The ESD varieties escaped or received less damage from pod borer and podfly, but varieties maturing after 15 November were severely damaged by both pests.

Bioefficacy studies showed that endosulfan 0.07% and monocrotophos 0.04%, decamethrin, fenvalerate, and cypermethrin sprays, and carbaryl and endosulfan 4% as dusts gave better control of pod borer than other insecticides.

Studies were also conducted on problems of spraying tall pigeonpea crops. We found that if the crop was sown in 7-m-wide strips separated by 3-m gaps, it could be effectively sprayed with a foot sprayer from both sides of the strip.

Extra-short-duration varieties of pigeonpea also fit well into integrated pest management (IPM) programs, which consider the pest as part of the ecosystem as a whole and use a combination of insecticidal, biological, and cultural methods to control the pest. Because the ESD varieties mature early, they escape the peak pest attack.

Pathology

In Haryana, pigeonpea cultivation began only recently; hence there is no problem of diseases. Wilt, root rot, and stem blight have been noticed sporadically, but caused no measurable economic damage. However, parents with multiple disease resistance/tolerance identified elsewhere are being used in the hybridization program.

Microbiology

Surveys on pigeonpea nodulation in farmers' fields have shown that native populations of pigeonpea rhizobia at most locations in Haryana are very poor (Table 3).

Table 3. Nodulation status of short-duration pigeonpea in Haryana, India.

District	Total number of locations	Nodulation (at number of locations)		
		Poor	Moderate	Good
Faridabad	42	34	7	1
Gurgaon	50	39	5	6
Hisar	33	31	2	-
Jind	22	19	2	1
Rohtak	*66*	57	9	-
Sonepat	72	57	12	3
Other districts (five)	190	142	41	7
Total	475	379	78	18

Reasons for poor nodulation of pigeonpea were investigated, and the high temperatures prevalent in this region were found to be the most important. High temperatures affect almost all the processes of nodule formation, root hair formation and flavonoid production being the most adversely affected. Efficient *Rhizobium* strains identified for pigeonpea are CC 1021, F4, IHP 195, PG 3, and PH 8666. In farmers' fields, a 9-20% increase in grain yield has been recorded with *Rhizobium* inoculation.

Prospects for Pigeonpea in Haryana

Pigeonpea in Haryana can be sown from March to mid-July. Varieties are now available to cover this extended sowing period. The area and production of pigeonpea are gradually increasing, but there is ample scope for further expansion. There is scope for simultaneously increasing production of mung bean and urd as well by intercropping them with pigeonpea. However, further efforts are needed to popularize the pigeonpea-wheat rotation.

There is a need to develop more high-yielding and dwarf ESD pigeonpea varieties. There is also a need to develop feasible and economically viable production technologies, particularly for plant protection.

Use of Extra-short-duration Pigeon pea in Rotation with Winter Crops in Punjab

H S Sekhon, P S Sidhu, and P S Phul[1]

Pigeonpea accounts for 15-16% of the area and 18-19% of the production of all pulse crops in India. It is grown for both grain and fuel; the sticks are considered high-quality fuel in rural areas and bring good economic returns to farmers.

Status of Pigeonpea in Punjab

Despite being a minor crop in Punjab until the early 1970s, pigeonpea now occupies second position among *kharif* (rainy-season) pulses in the state, although Punjab's contribution to the country's total production is negligible.

Traditionally, pigeonpea used to be grown as a border crop around sugarcane and cotton fields, on an insignificant area, and remained a neglected crop until the 1970s (Sidhu and Sandhu 1981). It was also grown in mixed crops or intercropped with maize, pearl millet, or sorghum, as a rainfed crop, in small pockets of Patiala and Ropar districts. The long-duration (8-9 months) local varieties were used for this purpose. These practices are still being followed.

Sole-cropping of pigeonpea began with the release of the short-duration (SD) variety T 21 (160 days) in 1973 and became popular with the release of an extra-short-duration (ESD) variety AL 15 (130-135 days) in 1981. It is now successfully cultivated as a sole crop in an irrigated double-cropping system (pigeonpea-wheat). The release of SD varieties increased pigeonpea area from about 3000 ha in 1975/76 to about 40 000 ha in 1985/86, with an average yield of 0.98 t ha^{-1}. But the area subsequently began to decline, and now stands at about 11 000 ha. However, our observations, particularly during the last 2-3 years, show that the area statistics are underestimates, since the area covered as a border crop under pigeonpea is not accounted for at all.

Cultivation of pigeonpea T 21 delayed sowing of the succeeding wheat crop, and in wet years, the crop gave excessive vegetative growth and low grain yields. Variety AL 15, although of much shorter duration, is determinate and therefore prone to pod-borer attack. To overcome the limitations of T 21 and AL 15, another dual-purpose, extra-short-duration (ESD) variety, AL 201 (130-135 days), was released in 1993.

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The average yield of these three varieties is around 1.5 t ha^{-1}. Efforts were made to break yield barriers through alternative approaches, such as heterosis breeding. As a result, the hybrid, PPH 4 (140-145 days), was released for general cultivation in Punjab in 1994. This new hybrid has an acceptable level of resistance to various biotic stresses and outyielded both the local control varieties-T 21 by 32.2% and AL 201 by 26.6%-in adaptive trials and by a slightly higher margin in research trials. Similarly, in the north-west plain zone (NWPZ), 1991-1993, PPH 4 ranked first and yielded 21.4% more than the control, UPAS 120, and 10.2% more than H 82-1 (1992 and 1993). In a coordinated agronomic experiment in 1993, PPH 4 surpassed the control, H 82-1, by 17.7% at Ludhiana.

Crop Rotations

The most common crop rotation involving pigeonpea is pigeonpea-wheat. However, with irrigation, pigeonpea can also be cultivated in other rotations: pigeonpea-barley, pigeonpea-chickpea/lentil/fieldpea, pigeonpea + mung bean/urd-wheat/barley. In rainfed areas, pigeonpea-fallow, pigeonpea-barley, pigeonpea + sorghum/pearl millet/maize-fallow/barley, pigeonpea + mung bean/urd/groundnut-fallow/barley rotations are followed.

Pigeonpea-potato (spring) and pigeonpea-sunflower (spring) systems are also gaining popularity. Recently, a system of transplanting *gobhi sarson* (a type of mustard) in late November or early December has been introduced, and pigeonpea-transplanted *gobhi sarson* may also become an important rotation. In the central districts of the state, the demand for pigeonpea fuel is so high that many farmers sow the tall early variety T 21 at the end of April or beginning of May and harvest the plants at the end of September, before they set seed, and thereafter sow *berseem (Trifolium alexandrinum)* as a fodder crop.

Constraints to Production

The major reasons for decline in area and low productivity of pigeonpea are

- Profit consciousness. The farmers have become highly market-conscious and prefer to grow the crops that give them the highest returns. Besides, large fluctuations in pigeonpea prices, depending upon the production, cause farmers to switch over to such assured crops as rice.

- Insect-pest damage. Insect damage to the pigeonpea crop can be severe, because of an almost complete lack of pest control at the farmer's level.

- Nonavailability of seed. Limited production and nonavailability of quality seed, particularly hybrid seed, at the appropriate time discourages pigeonpea cultivation.

- Poor adoption of production technology. Recommended practices need to be followed for high yields from the new pigeonpea varieties. Sowing on marginal soils, lack of seed treatment and fertilizer, improper time of sowing, low population densities, and insufficient weeding cause drastic yield reductions.

- Environmental factors. Occasional drought around mid-September, or late heavy rains at the end of September or early October lead to flower and pod drop, regrowth, and delayed maturity.
- Postharvest handling. Threshing, processing, and storage are often inadequate, and losses can be heavy.
- Social factors. Old beliefs, e.g., that pigeonpea causes swelling of joints, hamper increased consumption.

Impact of Agronomic Management

Numerous field experiments at Punjab Agricultural University revealed that the potential of improved varieties could be realized only when proper agronomic practices were followed. The optimum time of sowing for variety T 21 is the second half of May; for hybrid PPH 4, the last week of May to first week of June; and for AL 201 and AL 15, the first half of June. Delayed sowing of pigeonpea delays maturity and substantially reduces grain yields.

Maintaining the optimum density is very important to achieving high yields. Recent studies on population density and planting geometry showed that varieties AL 15, AL 201, and T 21 gave the highest yields when sown at a 50 cm x 25 cm spacing (8 plants m^{-2}), while hybrid PPH 4 gave the highest yield at a 67.5 cm x 25 cm spacing (5.9 plants m^{-2}). For higher yields, 15 kg N and 40 kg P_2O_5 ha^{-1} should be given as a basal dose. However, the P application is not necessary if pigeonpea follows wheat that received the recommended dose of P.

Although pigeonpea is supposed to suppress weeds better than other pulse crops, yield losses of about 29% have been observed in unweeded pigeonpea crops. Manual weeding done at 30 and 50 days after sowing (DAS) markedly increases the productivity of pigeonpea. Recent studies show that preemergence application of pendimethalin at 0.75 kg a.i. ha^{-1} + ridging at 50 DAS effectively controls weeds and gives higher yields. Interestingly, the intercropping of mung bean in pigeonpea (1:1) smothered weeds and reduced dry weight of weeds by 18.3% over unweeded sole pigeonpea (Sekhon et al. 1993). In a pigeonpea/mung bean intercrop, only one hand hoeing (30 DAS) was sufficient to check weeds, and the resulting grain yield was almost equivalent to that from two hand hoeings (30 and 50 DAS). The mung bean intercrop yielded 0.4 t ha^{-1} additional mung grain without reducing the yield of pigeonpea. The mid-May sowing of pigeonpea faced fewer weed problems than the early June sowing.

Being a deep-rooted crop, pigeonpea can withstand a fair amount of drought. However, if postrainy-season drought prevails, one irrigation at flowering is beneficial and enhances yields, but no irrigation should be given after the end of September, as it delays crop maturity.

Prospects for Pigeonpea in Punjab

With the development of the high-yielding hybrid PPH 4, a breakthrough in pigeonpea grain yield has been achieved. The measures taken by the Government (National Pulses Development Project and Technology Mission) to increase production and productivity of pigeonpea by providing farmers with necessary inputs have started yielding results. Twenty Frontline Demonstrations (FLD) involving the new hybrid PPH 4 and control cv AL 201 (0.2 ha each) were conducted in seven districts during 1994. On an average, PPH 4 yields surpassed the control variety by 19.9% (Table 1). The highest grain yields of PPH 4 (2.0 t ha^{-1}) and of AL 201 (1.6 t ha^{-1}) were achieved in Ludhiana district. However, farmers are convinced that it is possible to get 2.5 t ha^{-1} or more grain yield from hybrid PPH 4, following improved production and protection technology. The hybrid also yielded 10-15% extra fuel, considered higher quality than cotton or *jantar (Sesbania aculeata)* fuel in rural areas.

The data collected on the economics of cultivating hybrid PPH 4 in farmers' fields (Table 2) show that returns per hectare comparable to those from rice can be

Table 1. Performance of pigeonpea hybrid PPH 4 in Frontline Demonstrations, Punjab, India, 1994.

District	Number of trials	Mean yield (t ha^{-1})		Yield increase over control (%)
		PPH 4	AL 201	
Faridkot	5	1.4	1.2	12.9
Fatehgarh Sahib	2	1.8	1.5	22.3
Hoshiarpur	1	1.5	1.3	20.1
Jalandhar	3	1.7	1.4	19.6
Ludhiana	7	1.8	1.5	23.7
Patiala	1	1.8	1.5	21.4
Sangrur	1	1.8	1.5	17.5
Overall mean	20	1.7	1.4	19.9
Highest yield (Ludhiana)		2.0	1.6	28.6

Table 2. Economics of hybrid pigeonpea cultivation in farmers' fields, Punjab, India, 1994.

	Location	
	I	II
Area sown (ha)	0.4	0.4
Gross expenditue (Rs)	2 780.0	2 750.0
Grain yield (kg)	750.0	675.0
Price of grain (Rs kg^{-1})	10.4	12.2
Return from grain (Rs)	7 777.0	8 235.0
Return from fuel (Rs)	2 700.0	2 000.0
Total return (Rs)	10 477.0	10 235.0
Profit (Rs)	7 967.0	7 485.0

obtained if a price of Rs 10.0-12.0 kg^{-1} for pigeonpea is assured. Even if pigeonpea grain is sold at Rs 8.0 kg^{-1}, the higher yields from PPH 4 (grain and fuel) can bring in more income than other varieties grown in the state.

Another experiment during 1990/91, involving pigeonpea genotypes of different durations in the pigeonpea-wheat system, showed that high-yielding SD varieties, such as ICPL 83015 (128 days) and AL 15 (128 days), gave net returns of Rs 11 004 and Rs 10 453 ha^{-1}, respectively, whereas medium-duration variety Pusa 855 (154 days) gave a much lower net return of Rs 8342 ha^{-1}.

The future of the rice-wheat system in Punjab seems uncertain, because of the inherent constraints and declining yields, particularly of rice, during the last decade; thus the area under rice is likely to decrease in coming years. Furthermore, the heavy demand for pigeonpea seed (hybrid or variety) in the current year indicates good chances for enhancing pigeonpea cultivation. It is therefore expected that the release of PPH 4 is likely to open a new era in pigeonpea cultivation in the state, as this hybrid fits very well into the irrigated pigeonpea-wheat rotation.

Future Strategy

To boost pigeonpea production and yields and to reduce the gap between actual and potential yields, the emphasis should be on

- **Development and transfer of improved production and protection technology.** Development of location-specific technology; gearing up of extension machinery for transfer of technology through large-scale demonstrations on farmers' fields; training of farmers to produce genetically pure seed of varieties, hybrids, and parental lines of hybrids; design and manufacture of cheap and effective plant protection equipment.

- **Timely availability.** Timely availability of quality seed and other inputs in sufficient quantity.

- **Government's role.** Assured minimum support price of about Rs 12 000 t^{-1}; subsidy on inputs, such as seed, fertilizer, and pesticides; incentives to produce good quality seed, particularly hybrid seed.

- **Postharvest handling technology.** Availability of suitable machinery for threshing and more processing units near the production centers.

- **Surveys.** Block by block survey to find new niches for SD and ESD pigeonpea varieties and hybrids.

- **Economics of cropping systems.** Economics of cropping systems involving pigeonpea in comparison with other crops.

Conclusion

It can be concluded that the available SD varieties and improved production and protection technology indicate the potential for achieving higher pigeonpea yields. However, this potential is not being fully realized in farmers' fields. Thus there is an urgent need to identify the missing linkages to convert the potential into performance.

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Prospects for Extra-short-duration Pigeonpea in Gujarat

S B S Tikka, R M Chauhan, and R P S Ahlawat[1]

In Gujarat, pigeonpea ranks first among the pulse crops. It is grown on about 0.35 million hectares, accounting for 42% of the area and 52% of the pulse production.

The principal pigeonpea-growing districts are Bharuch and Surat in southern Gujarat; Panchmahals and Vadodara in central Gujarat, and Sabarkantha in northern Gujarat. Recently, the crop has been introduced into Saurashtra as an intercrop/relay crop with groundnut (Bharodia 1995). Pigeonpea is a minor crop in other districts of the state.

The yields of pigeonpea in Gujarat are low (700-900 kg ha^{-1}), because it is traditionally cultivated as a rainfed crop, with a predominance of medium- and long-duration varieties. The reasons for the low productivity of *kharif* (rainy-season) pigeonpea are

- Waterlogging at the seedling stage.
- Drought stress during the reproductive phase.
- Excessive weed infestation.
- High incidence of insect pests, particularly pod borer (*Helicoverpa armigera*) and podfly (*Melanagromyza* sp), and of diseases, particularly wilt (*Fusarium udum*) and stem blight (*Phytophthora drechsleri*).
- Poor production practices: low plant densities, low fertilizer use, etc.

There is tremendous scope for introducing extra-short-duration (ESD) pigeonpea, which can fit well into double- and multiple-cropping systems in different agroclimatic zones of the state. For example:

- in a pigeonpea-wheat rotation in Mehsana and Sabarkantha districts of northern Gujarat, with assured irrigation;
- as a postrainy-season crop in Bhal on conserved moisture;
- as a postrainy-season crop in the canal command areas of Tapi and Narmada, in Surat and Bharuch districts;
- as an intercrop with direct-seeded rice in southern and central Gujarat;
- after the harvest of transplanted rice, with irrigation as well as on conserved moisture, in Surat and Valsad districts;
- as a relay crop with groundnut in Saurashtra.

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Varietal Evaluation

During the 1994 rainy season, 14 determinate and 16 indeterminate ESD pigeonpea varieties were evaluated at Sardar Krushinagar (Tables 1 and 2). The best performers

Table 1. Performance of extra-short-duration determinate pigeonpea genotypes at Sardar Krushinagar, Gujarat India, rainy season 1994.

Genotype	Days to 50% flowering	Duration (days)	Grain yield (kg ha^{-1})
ICPL 4 (Control)	74	120	775
ICPL 151 (Control)	73	121	1025
ICPL 88009	73	124	671
ICPL 90002	73	122	448
ICPL 90000	73	121	723
ICPL 90011	74	123	483
ICPL 90012	72	121	1121
ICPL 91002	69	119	694
ICPL 91004	72	121	1015
ICPL 91007	76	133	306
ICPL 91008	70	123	590
ICPL 91011	72	120	910
ICPL 91028	*66*	122	646
ICPL 92030	*66*	123	635

Table 2. Performance of extra-short-duration indeterminate pigeonpea genotypes at Sardar Krushinagar, Gujarat India, rainy season 1994.

Genotype	Days to 50% flowering	Duration (days)	Grain yield (kg ha^{-1})
ICPL 4 (Control)	78	127	1250
UPAS 120 (Control)	78	127	1163
ICPL 88032	81	128	694
ICPL 88039	81	129	431
ICPL 89008	78	130	333
ICPL 89011	78	128	457
ICPL 90036	80	130	402
ICPL 90038	77	131	417
ICPL 90039	72	128	817
ICPL 91031	75	129	608
ICPL 91036	77	130	500
ICPL 92041	78	128	506
ICPL 92042	78	128	640
ICPL 92044	74	125	973
ICPL 92045	75	127	1027
ICPL 92047	74	129	577

among the determinate genotypes were ICPL 90012 (1121 kg ha^{-1}), ICPL 151 (1025 kg ha^{-1}), and ICPL 91004 (1015 kg ha^{-1}); among the indeterminate genotypes, ICPL 4 (1250 kg ha^{-1}), UPAS 120 (1163 kg ha^{-1}), and ICPL 92045 (1027 kg ha^{-1}).

Pigeonpea-wheat rotation in northern Gujarat

As the pigeonpea-wheat rotation is becoming popular in the northern Gujarat agroclimatic zone, an experiment was conducted at Sardar Krushinagar for 3 years (1992-1994) to evaluate the performance of 10 short-duration (SD) and ESD pigeonpea varieties (AL 15, AF 179, ICPL 87, ICPL 83015, ICPL 84023, ICPL 84031, ICPL 88001, Pusa 85, TAT 10, and T 21) in this rotation. A wheat variety recommended for late sowing (GW120) was sown after the harvest of each pigeonpea variety. Although pooled analysis showed nonsignificant varietal differences in pigeonpea yields, AF 179 gave a numerically higher yield (1226 kg ha^{-1}) than the others. Similarly, differences in yields of wheat sown after the harvest of pigeonpea were also nonsignificant; however, the numerically highest yield (2965 kg ha^{-1}) was from wheat sown after the harvest of variety AF 179.

On-farm testing

During the current (1995) rainy season, on-farm evaluation is being done in northern Gujarat of ESD pigeonpea varieties ICPL 87, ICPL 88009, and ICPL 88039, obtained from ICRISAT Asia Center at Patancheru, India. At Sardar Krushinagar, ICPL 87 flowered in 85 days, ICPL 88039 in 72 days, and ICPL 88009 in 60 days. Wheat variety GW 120 will be sown at all the test sites after the harvest of the pigeonpea.

Future Research

As there is tremendous scope for introducing ESD pigeonpea into existing cropping systems in the state, we need to generate information on production technology to increase pigeonpea yields by

- evaluating available ESD pigeonpea genotypes in different agroclimatic situations through on-farm testing;
- evolving appropriate production technology, considering sowing dates, population densities, fertilizer management, irrigation, in situ moisture conservation, etc;
- developing integrated pest management and disease control methods-particularly for pod borer, podfly, wilt, sterility mosaic disease, and phytophthora stem blight— for different agroclimatic situations.

Fortunately, Gujarat has a well-established system for research on pulses and on-farm testing in all eight agroclimatic zones. This will enable quick transfer of technology to help Gujarat farmers realize the full potential of the new pigeonpea varieties.

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Extra-short-duration Pigeonpea in Western Uttar Pradesh: Problems and Prospects

S K Srivastava[1]

Introduction

Pigeonpea is a unique crop species. Its beneficial effects on the entire farming system are well documented (Nene, in press). Traditionally, people of western Uttar Pradesh have preferred black gram *dhal* (split urd bean); however, urd area is dwindling rapidly, shrinking from 13 544 ha in 1983/84 to 2124 ha in 1993/94. Because of this factor, plus the increase in area under rice (from 144 542 ha in 1987/88 to 182 757 ha in 1993/94) and the migration of people into western Uttar Pradesh from the eastern part of the state and Bihar, consumer preference is now for pigeonpea dhal (split pigeonpea). Pigeonpea area has increased overall in western Uttar Pradesh (from 11 000 to 18 000 ha in the last 10 years), although only two districts-Bulandshahr and Ghaziabad-have contributed to this increase; average yield has also increased from 0.7 to 1.3 t ha^{-1} during this period.

Currently, pigeonpea is grown both as a sole crop and as a mixed crop with maize or fodder sorghum in the pigeonpea-wheat sequence; UPAS 120 is the most popular cultivar. Pigeonpea is also sown in single rows bordering sugarcane fields. In some rainfed sandy soil areas, long-duration pigeonpea, often mixed with groundnut, is also grown.

Pigeonpea is broadly classified into short- (<150 days), medium- (151-180 days), and long-duration (180 days) groups (Reddy 1990). The short-duration types are further classified into short-duration (SD) and extra-short-duration (ESD) types (Gupta et al. 1989). The ESD genotype ICPL 85010 was first brought into western Uttar Pradesh from ICRISAT by a farmer, Dr J S Verma of village Bhikanpur (Ghaziabad district), in 1992. Its performance was so encouraging that the Krishi Vigyan Kendra procured more seed from ICRISAT and tested it in diverse situations. This paper discusses the performance of UPAS 120 and ICPL 85010 so far and prospects for increasing area and production of pigeonpea in western Uttar Pradesh.

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Srivastava, S.K. 1996. Extra-short-duration pigeonpea in western Uttar Pradesh: problems and prospects. Pages 27-33 *in* Prospects for growing extra-short-duration pigeonpea in rotation with winter crops: proceedings of the IARI/ICRISAT Workshop and Monitoring Tour, 16-18 Oct 1995, New Delhi, India (Laxman Singh, Chauhan, Y.S., Johansen, C., and Singh, S.P., eds.). New Delhi 110 012 and Patancheru 502 324, Andhra Pradesh, India: Indian Agricultural Research Institute and International Crops Research Institute for the Semi-Arid Tropics.

Performance of UPAS 120 and ICPL 85010

Duration

Observations were made on both demonstration plots and other farmers' plantings of pigeonpea. The minimum duration of UPAS 120 sown in June was about 155 days (Table 1). Early sowing delayed maturity, primarily because pigeonpea is photo-period-sensitive. Flowering in this crop is initiated when daylength becomes progressively shorter (van der Maesen 1990). ICPL 85010 matured 20-25 days earlier than UPAS 120.

Table 1. Duration of two pigeonpea varieties in Ghaziabad district of western Uttar Pradesh, India.

	Duration (days)	
Month of sowing	UPAS 120[1]	ICPL 85010[2]
April	185-210	165-200
May	180-185	155-165
June	155-180	130-155

1. Short-duration variety.
2. Extra-short-duration variety.

Observations on farmers' fields show that water deficit at the pod-formation stage adversely affects synchrony; crops that suffered such water deficit matured 5-10 days later than those with adequate water, although sown on the same date. Studies are needed to correlate crop duration and maturity with photoperiod, temperature, and source-sink relationship as affected by soil moisture and nutrient conditions.

Plant height

Plant height of SD pigeonpea varies according to location (latitude, altitude) and time of sowing. Exposure of SD varieties to long-day conditions by early sowing prolongs their vegetative phase and increases plant height (Remanandan 1990). In Ghaziabad district (1993-95), UPAS 120 attained a height of 3 m in March, April, and May sowings and 1-1.5 m in June sowings. ICPL 85010 remained 1.5-2.0 m tall in March, April, and May sowings and 1-1.5 m in June sowings.

ICPL 85010 was sown in mid-May 1995 at Bhikanpur village in Ghaziabad district two sites, one near an irrigation channel and one away from it. The first plot had more soil moisture, because of seepage from the channel, than the second. The plant height, stem diameter, and overall podding of pigeonpea were all greater in the first plot, indicating that proper water management could give better plant growth and grain yield.

Plant pathogens, insect pests, and weeds

The plant pathogens *Phytophthora drechsleri* f.sp. *cajani* and *Rhizoctonia bataticola* reduced pigeonpea plant populations; however, their incidence was localized. *P. drechsleri* is serious under excess moisture; *R. hataticola,* under drought.

The predominant species of insect pests in the 1995 rainy season were the pigeonpea leaf webber, cowpea pod borer, gram pod borer, cow bug, blister beetle, and grasshopper. Only a few cow bugs and blister beetles had been recorded during 1993 and 1994. But in the last 2 years, grasshoppers have multiplied in astronomical numbers and inflicted catastrophic damage on fodder sorghum. Although grasshoppers did not damage pigeonpea leaves, they girdled young branches, which then withered and died.

Srivastava (1993) and Chaudhary and Sachan (1995) reported that for maximum economic returns, insecticides should be applied at flowering and podding stages. In our current demonstrations, pod-boring insects were successfully controlled with a single insecticide application at podding stage. A large proportion of pigeonpea flowers-often as much as 90%-are shed without setting pods, and pigeonpea can compensate completely for the loss of all developing pods for up to 2 weeks after the start of flowering (Sheldrake 1984).

Of the weeds in pigeonpea, *Trianthema monogyna* was most dominant, with dense and prolific growth during June and July. This weed completes its growth in August, but germinates again and poses a serious problem to *toria* (a short-duration oilseed crop) in September.

Population density

Farmers of western Uttar Pradesh sow all their grain crops, except rice, by broadcasting. For these demonstrations, some farmers sowed pigeonpea in rows, in furrows made with a tractor tiller, which created a wide row spacing. Plant populations of broadcast-sown and row-planted ICPL 85010 varied widely; this variation was due to poorly defined seeding rates, unequal distribution of seeds during broadcasting, death of germinating seeds due to drought and high temperatures, and infection by *R. hataticola* and *P. drechsleri.* Practical experience has shown that populations can be better controlled when seed number rather than seed weight is used for calculating seeding rates. Guides for determining wheat seeding rates based on seed size have been calculated (Murphy et al. 1987).

In pigeonpea, 100-seed weight is a variable character. In some ICRISAT trials, it ranged from 9 g to 12.7 g for both ICPL 85010 and UPAS 120, and from 10.3 g to 12 g for ICPL 151 (ICRISAT 1993). Currently recommended seeding rates are generalized for a group of varieties; for example, a rate of 12-15 kg ha^{-1} for T 21 and UPAS 120 and 20-25 kg ha^{-1} for ICPL 151 and ICPL 87.

A preliminary examination of the relationship of seed weight, volume, and number was done for six pigeonpea varieties. We found considerable differences in number of seeds per 10 g, which ranged from 114 seeds for ICPL 85010 to 166 seeds for UPAS

1.20. Thus, use of seed number would seem a more rational approach to determining seeding rate than use of seed weight.

Date of sowing

The recommended practice is to sow SD pigeonpea in the second half of June; however, in farmers' fields, sowing may start as early as the last week of April. Farmers with irrigation facilities prefer to sow pigeonpea early, to ensure that wheat can be sown by 20 November and that pigeonpea fields are not severely infested by the weed, T. *monogyna.* Chemical weed control is not popular, and hand weeding is hindered by rainfall; thus June-July sowings are badly infested by this weed.

Chauhan (1990) has listed some advantages of April-sown SD pigeonpea and has cited an experiment in Ludhiana in which SD pigeonpea T 21, sown on 1,15, and 30 June and 15 July yielded 2.0, 1.9,1.7, and 1.5 t ha^{-1}, respectively. However, in Hisar, ICPL 85010 gave varying results with different sowing dates; in 1986, yields obtained from sowings of 7 April, 25 June, and 28 July were 3.8, 2.6, and 2.1 t ha^{-1}, respectively, while yields obtained in 1987 from sowings of 1 May, 30 June, and 28 July were 2.8, 2.9, and 3.0 t ha^{-1}, respectively (ICRISAT 1989). Crops sown in April-May generally matured 15-20 days earlier and produced more stalks, total dry matter, and grain yield than those sown in June-July. But the potential of this early-sown crop is limited by its requirement for several irrigations. The plants also grow 3 m tall, posing problems for insect control. Extra-short-duration types (e.g., ICPL 85010) show stability over sowing dates and remain <2 m tall. Their potential is being tested on-farm.

Presence of indeterminate type in ICPL 85010

Indeterminate-type tall plants have always been recorded in plots of the determinate variety, ICPL 85010. These were only a few when fresh seed from ICRISAT was sown; however, when seed collected from such plots was sown, the number of indeterminate plants increased, because of outcrossing in pigeonpea and because the determinate character is recessive.

Yield and yield potential

The average yields obtained in demonstration plots suggest that ICPL 85010 is at par with UPAS 120. Pod number increased in plants near the irrigation channel, which suggests that ICPL 85010 has a high yield potential, as the most important variable determining yield is pod number per unit area (Sheldrake 1984).

Strategy for Increasing Pigeonpea Cropping

The pigeonpea area in western Uttar Pradesh can be increased in several ways.

1. **By demonstrating potential yield.** Pigeonpea is grown by medium- and large-scale farmers, who use relatively few inputs to obtain an average yield of 1.0-1.5 t ha^{-1}. It is essential that potential yield be demonstrated on small plots of about 1000 m^2. This would attract small-scale farmers also to grow pigeonpea.

2. **By overcoming major constraints limiting pigeonpea area.** Certain major constraints must be overcome if farmers are to be encouraged to grow pigeonpea.

   Soil salinity and soil sickness. Pigeonpea is relatively sensitive to soil salinity; therefore, its cultivation on saline soils should be avoided (Johansen 1990). Other soil problems also arise with continuous pigeonpea cropping. In an interview conducted in Ghaziabad district (n=30), two-thirds of the farmers reported that pigeonpea grown on the same plot in consecutive years has poor vigor and yields less in the second and subsequent years. Because of this, farmers either change the field or discontinue pigeonpea for 1 or 2 years. The depletion of soil phosphorus (P) may be an important reason for the declining vigor and yield of pigeonpea. Farmers of this region usually grow pigeonpea without application of fertilizers. Pigeonpea roots have the ability to tap both Fe-P and Ca-P from the soil (Johansen 1990). Further, in western Uttar Pradesh, studies have shown that as the sowing of pigeonpea was progressively delayed from June to July, response to P increased, while yield declined (Rathi et al. 1974). Allelopathic effects of pigeonpea litter have also been reported (Nene and Sheila 1990; Ohwaki et al. 1993), and there may be a buildup of pigeonpea-specific pests and diseases (e.g., fusarium wilt, phytophthora blight, nematodes, etc.) under continuous pigeonpea cropping. These aspects need further investigation. Farmers have not reported any adverse effect of pigeonpea on wheat or vice versa.

   Animal damage. Free-roaming *nilgai* (blue bulls) are attracted to ESD pigeonpea of short stature. Strategies are needed to discourage them and other animals that cause damage to the pigeonpea crop.

3. **By broadening spectrum of pigeonpea in cropping systems.** There is considerable scope for introducing pigeonpea into various cropping sequences in Uttar Pradesh. Some possibilities are listed here, as well as the essential prerequisites to introducing pigeonpea into these systems.

   Pigeonpea-potato. Some newly developed ESD varieties, such as ICPL 85010, offer good prospects for a pigeonpea-potato sequence. However, such a cropping sequence is possible only if pigeonpea vacates the field by the first week of October.

   Pigeonpea as a substitute for late-sown sugarcane. The optimum time to sow sugarcane is in March-April; delaying sowing until May, after the wheat harvest, reduces sugarcane yields to 20-40 t ha^{-1}. Before the sugarcane matures, many new tillers emerge and attain considerable growth. Farmers call this 'poglae.' During harvest these tillers are left intact, and the following year's crop (poglae + ratoon) yields 80-100 t ha^{-1}. Pigeonpea followed by a fodder crop or pigeonpea followed by a vegetable crop may be alternatives to late-sown sugarcane sown in April-May, after the wheat harvest. Sugarcane could then be sown at the optimum time the following year.

Conclusion

Observations and demonstrations have shown that ESD pigeonpea ICPL 85010 is a good substitute for UPAS 120 in western Uttar Pradesh. It matures 20-25 days earlier than UPAS 120, allowing wheat to be sown in the first half of November. Popularization of this variety and similar ESD types would help diversify the pigeonpea varieties grown in this region; however, several aspects of their cultivation still need research and demonstration.

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Table 2. Yield, yield equivalents, and economics of different cropping systems, Warangal, Andhra Pradesh, India, 1994/95.

Cropping system	Crop yield ($t\ ha^{-1}$)		Yield equivalents ($t\ ha^{-1}$)[1]		Total ($t\ ha^{-1}$)	Gross income (R+P) ($Rs\ ha^{-1}$)	Net income (R+P) ($Rs\ ha^{-1}$)	Cost: benefit ratio
	Rainy season (R)	Postrainy season (P)	Rainy season (R)	Postrainy season (P)				
ESD - PP[2]	1.0	0.8	1.0	0.8	1.9	22 561	13 636	1.5
ESD - Groundnut	1.0	1.6	1.0	1.4	2.5	29 685	19 343	1.9
ESD - Maize	1.0	5.0	1.0	1.7	2.8	33 858	24 573	2.6
ESD - Sunflower	1.0	1.8	1.0	1.8	2.8	33 377	24 306	2.7
Green gram (GG) - PP	0.5	0.9	0.4	0.9	1.2	15 470	7 221	0.9
GG - Groundnut	0.5	2.0	0.4	1.8	2.1	26 321	16 644	1.7
GG - Maize	0.5	4.8	0.4	1.7	2.1	25 868	17 254	2.0
GG - Sunflower	0.5	1.6	0.4	1.6	1.0	23 821	15 414	1.8
Groundnut - PP	1.2	1.1	0.8	1.1	2.0	23 631	14 619	1.6
ESD - Groundnut	1.2	1.5	0.8	1.3	2.1	25 846	15 320	1.5
ESD - Maize	1.2	4.3	0.8	1.5	2.3	28 557	19 092	2.0
ESD - Sunflower	1.2	1.9	0.8	1.9	2.7	31 873	22 616	2.4
Sesame - PP	0.02	1.3	0.02	1.3	1.3	16 407	9 045	1.2
Sesame - Groundnut	0.02	1.7	0.02	1.6	1.6	20 106	11 357	1.3
Sesame - Maize	0.02	5.0	0.02	1.7	1.8	22 489	14 802	1.9
Sesame - Sunflower	0.02	2.1	0.02	2.1	2.1	25 369	17 890	2.4
SEm ±	-	-	-	-	0.11	-	1 406	-
CD 0.05	-	-	-	-	0.24	-	2 903	-
CV (%)	-	-	-	-	-	-	-	-

1. The yields of rainy and postrainy season crops were converted to pigeonpea yield equivalents of rainy and postrainy seasons.
2. ESD = extra-short-duration pigeonpea; PP = medium-duration pigeonpea.

Future Research Priorities

Future areas of research need to focus on

1. Identifying sources of resistance to M. *testulalis* and tolerance of prolonged drought at the reproductive phase, and incorporating such resistance into a good agronomic base.
2. Standardizing agrotechniques for ESD pigeonpea cultivation.
3. Identifying genotypes for spring cultivation/January sowing in rice-based cropping systems.

Target Environments in Andhra Pradesh

1. The northern Telangana zone has the potential for expanding ESD pigeonpea cultivation up to 250 000-300 000 ha in existing cropping systems; this will need backup research on the problems identified.
2. The southern Telangana zone has the potential for expanding pigeonpea area up to 150 000-200 000 ha in existing cropping systems; this will need on-farm research to popularize the new genotypes.
3. The scarce-rainfall zone has the potential for cultivating 100 000-150 000 ha of pigeonpea; this will need on-station research for further planning.

Because of its superior performance and because it fits into existing cropping systems, ICPL 84031 was recently released, under the name of Durga, by the Andhra State Seed Sub-Committee on Varietal Release for general cultivation in the northern Telangana zone of Andhra Pradesh.

The Status of Pigeonpea Research and Prospects for Extra-short-duration Pigeonpea in Nepal

C R Yadav[1] and R K Neupane[2]

Introduction

Grain legumes occupy 13% of the total cultivated area of Nepal and rank fourth in area and production after rice, maize, and wheat. In the last 10 years, the area of pigeonpea has almost doubled, but yields have remained more or less constant (Table 1).

Table 1. Area, production, and yields of pigeonpea in Nepal.

Year	Area ('000 ha)	Production ('000 t)	Average yield (t ha^{-1})
1983/84	12.7	4.8	0.4
1984/85	14.3	10.5	0.7
1985/86	16.0	12.2	0.8
1986/87	17.5	13.3	0.8
1987/88	18.5	9.2	0.5
1988/89	17.9	12.3	0.7
1989/90	18.9	13.3	0.7
1990/91	17.9	12.0	0.7
1991/92	17.5	11.3	0.6
1992/93	22.8	16.5	0.7
1993/94	22.6	16.4	0.7

Source: Central Bureau of Statistics, Agricultural Statistics Department, Nepal, 1994.

Pigeonpea is an important summer legume crop, grown in different cropping patterns in the *Tarai* (foothills of the Himalayas) and inner Tarai zones and the lower valleys up to 800 m above sea level. It is grown both as a sole crop and as a mixed or intercrop in the western Tarai; in the central and eastern part of the country, it is more commonly sown on bunds around rice fields.

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Yadav, C.R., and Neupane, R.K. 1996. The status of pigeonpea research and prospects for extra-short - duration pigeonpea in Nepal. Pages 38-42 *in* Prospects for growing extra-short-duration pigeonpea in rotation with winter crops: proceedings of the IARI/ICRISAT Workshop and Monitoring Tour, 16-18 Oct 1995, New Delhi, India (Laxman Singh, Chauhan, Y.S., Johansen, C., and Singh, S.P., eds.). New Delhi 110 012 and Patancheru 502 324, Andhra Pradesh, India: Indian Agricultural Research Institute and International Crops Research Institute for the Semi-Arid Tropics.

Almost all pigeonpea cultivars grown in Nepal are medium-duration (MD) and long-duration (LD) types. Rainfed LD pigeonpea experiences terminal drought stress. The low temperatures during December and January adversely affect growth and grain yield.

We are currently evaluating the prospects for growing short-duration (SD) and extra-short-duration (ESD) pigeonpea genotypes in the rainy and postrainy seasons, and some genotypes have been found promising.

Constraints to Productivity

The national average yield of pigeonpea is 727 kg ha^{-1}. This low yield can be attributed to several constraints, which were identified and prioritized during the diagnostic survey of production areas in 1991:

Insect pests. Pod borers, mainly *Helicoverpa armigera,* podfly *(Melanagromyza* sp), and termites (*Odontotermes* sp) cause considerable damage. Spraying equipment is not available.

Diseases. Sterility mosaic disease (SMD), wilt (*Fusarium udum)* and phoma stem canker (*Phoma cajani)* reduce yields.

Lack of improved varieties. Currently grown varieties are predominantly tall, LD types (270 days), which are generally low-yielding.

Weather. Excessive rain, cloudy weather, and low temperatures cause flower drop and poor pod setting.

Weeds. Weed management is difficult: chemical control is expensive and hand weeding, labor-intensive.

Economics. Lack of a support price makes profits from pigeonpea cultivation uncertain.

Pigeonpea Research in Nepal

In Nepal, pigeonpea research was initiated in 1977, with some local and exotic materials. Local landraces were collected and characterized in 1989. Research was mainly carried out at the Regional Agricultural Research Station (RARS), Nepalganj, in the west and the National Oilseeds Research Program (NORP) in the east/central Tarai. The main objectives of pigeonpea research are to identify

- MD and LD cultivars with bold seed, disease resistance/tolerance, and high and stable yield for rainy-season sowing;
- SD and ESD types with disease resistance/tolerance, bold seed, and high yield ability for both rainy- and postrainy-season sowing in pigeonpea-wheat, short-duration rice-pigeonpea, or maize-pigeonpea cropping patterns;

- sources of resistance to major diseases (wilt and SMD) for use in the varietal improvement program;
- methods of controlling pod borer and podfly;
- appropriate agronomic practices and optimum sowing densities, weeding methods, and intercropping and mixed-cropping ratios involving pigeonpea and other crops.

Status of Research on Short-duration Pigeonpea

Varietal evaluation

Considering the feasibility of double-cropping with SD pigeonpea, we evaluated several varieties from ICRISAT in the western (NARS, Nepalganj) and eastern (Jitpur and Nawalpur) Tarai regions. The main pulse research station at Rampur is not a representative site for the central Tarai.

Varieties maturing in 160-170 days at Nepalganj yielded 1.5-2.0 t ha^{-1} grain (at par with the control, Rampur Rahar 1, which matures in 180 days). The most promising varieties were UPAS 120 and ICPL numbers 151, 84031, 86005, 87101, 87105, and 89011.

In the eastern Tarai (tests at Jitpur and Nawalpur), UPAS 120, ICPL numbers 146, 84032, 86005, 86012, and 87105, and Rampur Rahar 1 have been chosen for on-farm tests. These SD varieties have wide adaptation, mature in 160 days, and have a yield potential of 2 t ha^{-1}. These tests were conducted in the rainy season, in July-August sowings.

We also evaluated some of the SD and MD pigeonpea lines in postrainy-season sowings to fit in the early rice-pigeonpea or maize-pigeonpea double-cropping system in rainfed uplands in the eastern Tarai. The SD pigeonpea lines matured in 140 days and gave a mean grain yield of 1.1 t ha^{-1}, whereas the MD lines matured in 190 days and yielded 0.6 t ha^{-1}. Further testing of SD lines will be pursued in these cropping systems.

Agronomy

Traditionally, pigeonpea is grown rainfed, as a sole crop or a mixed crop with maize in the western part of the country. In the eastern part, it is commonly sown on rice-field bunds or grown as a sole crop or a mixed crop with maize in upland areas. Agronomic experiments on date of sowing, weed control, and intercropping were initiated in 1988/89.

The study conducted at Rampur on date of sowing showed that the third week of June was the optimum time for sowing SD pigeonpea, giving the highest yields (Neupane et al. 1994). In intercropping trials consisting of sole-cropped pigeonpea and five crop combinations, the highest gross monetary returns were obtained from the pigeonpea/maize intercrop at Rampur, Nawalpur, and Nepalganj. Intercrops did not affect the yield of pigeonpea variety Rampur Rahar 1. In another trial conducted at Rampur, the intercrop of pigeonpea/maize in a 2:1 ratio gave gross returns 7.1% higher than those from sole-cropped pigeonpea. The compatibility of early maize Arun-2 with pigeonpea was confirmed by intercropping trials conducted during 1989-91.

In weed control trials conducted at Rampur, preemergence application of Lasso® (alachlor) @ 2.5 L a.i. ha^{-1} + one hand weeding was equivalent to two hand weedings 25 and 45 days after sowing. The marginal benefitrcost ratio for application of Lasso® was 2:1, suggesting the benefits of herbicide application.

Pathology

To identify sources of SMD resistance, efforts were made to develop screening nurseries in 1987/88. Several SMD-resistant lines have been identified: Bahar, ICPL 366, ICP 7035, ICPL 86012, PR 5114, PR 5151, PR 5166, and Rampur Rahar 1. A collaborative program with ICRISAT has generated SMD-resistant material from the cross ICPL 366 x Nepalganj local, to enable selection of SMD-resistant, high-yielding LD pigeonpea genotypes.

Wilt-resistant materials from ICRISAT and derivatives of crosses between Bageshwari and ICPL 87126 are being evaluated in farmers' fields in Banke and Bardiya in the western Tarai region. The lines ICP 9174-243 and ICP 9174-2286, ICPL 87131, ICPL 87133, ICPL 93006, and selections from the cross, ICPX 850363, were selected from the wilt screening nursery in 1994/95.

Entomology

Podfly and pod borers are serious biotic constraints to pigeonpea production in Nepal. Endosulfan, Decis®, or Rogor® sprays @ 1.5 L ha^{-1} increased grain yields of pigeonpea. In on-farm trials conducted at Banke, Bardiya, and Sarlahi, chemical control measures (spray of Rogor® at flowering, endosulfan at initial podding stage, and Rogor® 10-12 days later) gave an overall yield increase of 31.1% over the untreated control. However, spraying pigeonpea is very difficult, because no suitable equipment is available.

Prospects for Short- and Extra-short-duration Pigeonpea

Research on and surveillance of diseases and pests is needed to strengthen plant-protection measures for SD and ESD pigeonpea. Seed production and storage facilities also need attention. The most immediate need is to develop or release SD pigeonpea varieties maturing within 150 days. This will facilitate the adoption of pigeonpea-wheat, short-duration rice-pigeonpea, and maize-pigeonpea rotations in Nepal.

Acknowledgments

We express our deep gratitude to Mr. S.B. Nepali, Executive Director, and Mr. R.P. Sapkota, Director, Crops and Horticulture Research, NARC, for providing us the opportunity to participate in this meeting and to ICRISAT for providing financial support.

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Prospects for Extra-short-duration Pigeon pea in Bangladesh

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Introduction

In Bangladesh, pulses form an important source of protein in both human diet and animal feed; they also improve soil fertility through biological nitrogen fixation. Pulses are grown mainly under rainfed conditions, with minimum inputs. They occupy about 0.7 million hectares, with a total production of about 0.5 million tons of grain (BBS 1993). However, both area and production of pulses are declining with the expansion of irrigation facilities, which encourage the cultivation of such crops as *boro* (winter-spring season) rice and wheat. The present availability of pulses is only 12 g per capita per day, which is much lower than the optimum requirement (Kumar et al. 1994).

Of the pulses grown in Bangladesh, pigeonpea is a minor crop, grown mainly in the northwestern part of the country (Virmani et al. 1991). It occupies 1.2% of the total pulse area, with an average yield of 700 kg ha^{-1} (BBS 1993). Traditionally, long-duration (LD) pigeonpea cultivars are sown as mixed crops with *aus* (postrainy season) rice, jute, finger millet, etc., in April-May and harvested during February-March. Because they require about 300 days to mature (Rahman 1991), these cultivars are not suitable for sole-cropping and do not fit well into existing cropping patterns. The recently introduced short-duration (SD) pigeonpea genotypes, which are less photoperiod-sensitive than traditional cultivars (Lawn and Troedson 1990), may have some promise for inclusion in existing cropping patterns in some specific areas of the country. This paper describes the recent developments in and prospects for future research on SD pigeonpea cultivation in Bangladesh.

Soils and Climatic Requirements

Pigeonpea is a tropical crop. As it prefers warm weather with relatively high temperatures, it is mainly grown during the rainy season in northern Bangladesh. On the other hand, it can be grown throughout the year in the southeastern part of the country, where winter temperatures remain high enough to support pigeonpea cultivation.

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Saha, R.R., Ahmed, J.U., Malek, M A , and Ahad Miah, A. 1996. Prospects for extra-short-duration pigeonpea in Bangladesh. Pages 43-49 *in* Prospects for growing extra-short-duration pigeonpea in rotation with winter crops: proceedings of the IAR1/ICRISAT Workshop and Monitoring Tour, 16-18 Oct 1995, New Delhi, India (Laxman Singh, Chauhan, Y.S., Johansen, C., and Singh, S.P., eds.). New Delhi 110 012 and Patancheru 502 324, Andhra Pradesh, India: Indian Agricultural Research Institute and International Crops Research Institute for the Semi-Arid Tropics.

Pigeonpea can be grown on a wide range of soils, varying from sandy loam to heavy clay soils (Jeswani and Baldev 1990). With its deep root system, it is fairly drought-tolerant but very sensitive to waterlogging, especially at early growth stages.

Cultivation Constraints

The constraints to production and adaptation of SD pigeonpea in Bangladesh are

- low research inputs;
- lack of high-yielding SD cultivars;
- nonavailability of SD pigeonpea seed;
- competition with major crops, such as rice, wheat, etc.
- disease and insect infestation;
- prevailing drought in the winter season;
- lack of proper management practices.

Progress in Pigeonpea Research

Coordinated research work on pigeonpea was initiated in 1979, under the Pulses Improvement Program of the Bangladesh Agricultural Research Institute (BARI). At first, some SD pigeonpea lines were introduced from ICRISAT and the United States Department of Agriculture (USDA); of these, 76012 was found promising because of its short duration (125-135 days) and good yield (2 t ha^{-1}). This line was also found suitable as a mixed crop with urd in the aus rice-urd-fallow cropping pattern in the northern part of the country (BARI 1990).

Some research work on medium-duration (MD) and SD pigeonpea genotypes was also carried out at the Regional Agricultural Research Station of BARI, Hathazari, Chittagong, from 1987 to 1995. The Chittagong region, in southeastern Bangladesh, has high annual rainfall (around 3000 mm), soil with good moisture-holding characteristics, and winter temperatures that are higher than in other parts of the country (Fig. 1). During 1987/88 and 1988/89, it was determined that SD pigeonpea genotypes could be grown during the winter in rice fallows in the aus rice-aman (rainy season) or rice-fallow cropping pattern (BARI 1988, 1989) (Table 1). However, although vegetative growth was satisfactory, reproductive growth was devastated by podfly.

In a study on the performance of 10 SD pigeonpea genotypes in the hilly areas, sown in the rainy season, maximum yields of 1 t ha^{-1} were recorded, which may be due to high rainfall causing excessive vegetative growth, flower drop, infestation of *Maruca testulalis,* and suboptimal plant populations (Table 2). In another study with ICPL151, using different population densities, 20 plants m^{-2} produced the maximum grain yield of around 2 t ha^{-1} (Table 3).

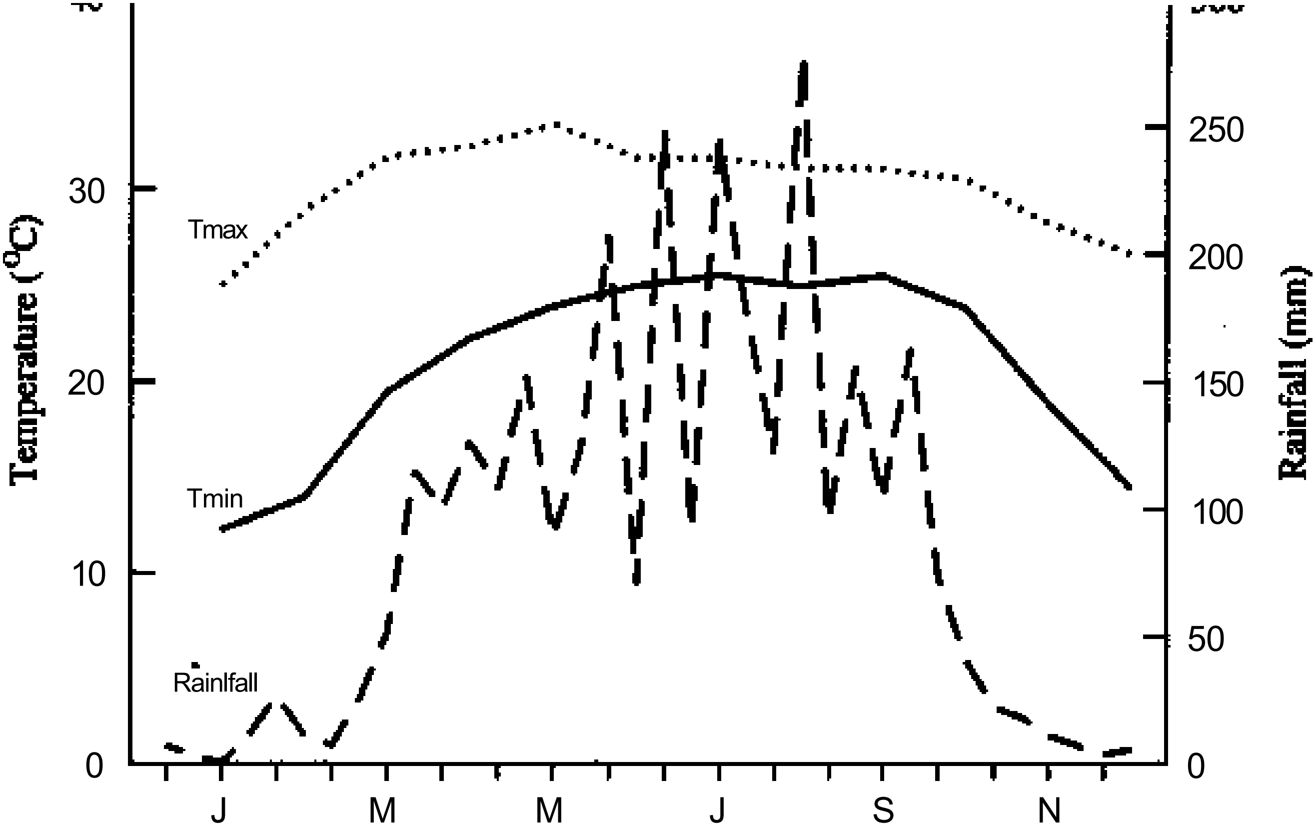

Figure 1. Average monthly temperatures and 10-day average rainfall patterns, Regional Agricultural Research Station, Chittagong, Bangladesh, 1987-94.

Table 1. Pods per plant and grain yield of pigeonpea genotypes sown on two dates in 1987/88 and 1988/89 in *aman* (rainy season) fallows, Regional Agricultural Research Station, Hathazari, Chittagong, Bangladesh.

	Pods plant^{-1}		Grain yield (kg ha^{-1})	
Treatment	1987/88	1988/89	1987/88	1988/89
Date of sowing[1]				
D1	29	26	490	280
D2	30	27	230	220
Significance[2]	NS	NS	**	*
Genotype				
ICPL 87	24	21	370	230
ICPL 95	35	27	380	250
ICPL 151	24	22	270	220
ICPL 161	35	27	300	300
ICPL 186	35	33	360	240
ICPL 83006	29	27	450	310
ICPL 83024	25	20	250	180
ICPL 87114	29	24	400	290
UPAS 120	35	29	390	220
LSD (P = 0.05)	1.9	5.5	60	40
Interaction	**	*	•	*

1. DI = 23 Dec 1987 and 4 Dec 1988; D2 = 15 Jan 1988 and 24 Dec 1988.
2. NS = Nonsignificant; * = significant difference at P<0.05; ** = significant difference at P< 0.01.

Table 2. Plant height branches per plant, and grain yield of 10 short-duration pigeonpea genotypes, Regional Agricultural Research Station, Hathazari, Chittagong, Bangladesh, rainy season 1991/92[1].

Genotype	Plant height (cm)	Branches plant^{-2}	Grain yield (kg ha^{-1})
ICPL 151	118 c[2]	8.7 cd	990 a
ICPL 83006	112c	7.0 e	730 cd
ICPL 83015	90 d	8.0 cde	650 cd
ICPL 84023	77 e	7.7 de	590 d
ICPL 85014	115c	9.4 bc	940 ab
ICPL 85045	187 a	11.2a	1010a
ICPL 86009	151b	5.3 f	700 cd
ICPL 86020	141 b	8.5 cde	850 ab
ICPL 89008	124 c	7.6 de	800 bc
Manak	111 c	10.5 ab	1000 a

1. Date of sowing: 9 Jul 1991.
2. Values within a column followed by the same letter do not differ significantly at the 0.05 level.

Table 3. Plant dry weight pod number, and grain yield of short-duration pigeonpea genotype ICPL 151 at different population densities, Regional Agricultural Research Station, Hathazari, Chittagong, Bangladesh, rainy season 1991/92[1].

Population density (plants m^{-2})	Plant dry weight at harvest (g plant^{-1})	Pod number plant^{-1}	Grain yield (t ha^{-1})
40	16.4 c[2]	29 e	1.9 a
20	34.8 b	48 d	1.9 a
10	44.2 ab	61 c	1.2 b
7	49.6 a	79 b	1.2 b
5	51.4 a	91b	1.0 b
3	51.9 a	106a	0.4 c

1. Date of sowing: 9 Jul 1991.
2. Values within a column followed by the same letter do not differ significantly at the 0.05 level.

When SD pigeonpea is sown in the late rainy season, plant growth is reduced, resulting in short plants and fewer branches. But high population density may be able to overcome the yield loss due to dwarfing of the plant. To test this, a population density trial with two pigeonpea genotypes was carried out in the late rainy season, 1992/93. In this study, genotype ICPL 85045 gave the maximum yield at 33 plants nr^{2} (Table 4). An experiment with three SD pigeonpea genotypes sown on two different dates showed that ICPL 332 produced the highest grain yield, of about 1.5 t ha^{-1}, in the mid-September sowing (Table 5).

Table 4. Plant dry weight and grain yield of two short-duration pigeonpea genotypes at three population densities, Regional Agricultural Research Station, Hathazari, Chittagong, Bangladesh, rainy season, 1992/93[1].

Population density (plants m^{-2})	Plant dry weight at harvest (g $plant^{-1}$)	Pod number $plant^{-1}$	Grain yield (kg ha^{-1})
ICPL151			
33	2.2	10.3 c[2]	880 b
25	2.9	12.2 c	900 b
20	3.4	16.0 c	698 cd
ICPL 85045			
33	2.4	12.0 c	1086 a
25	3.2	14.5 b	788 bc
20	3.9	17.3 a	580 d

1. Date of sowing: 3 Oct 1992.
2. Values within a column followed by the same letter do not differ significantly at the 0.05 level.

Table 5. Performance of some pigeonpea genotypes sown on two dates, Regional Agricultural Research Station, Hathazari, Chittagong, Bangladesh, 1994/95.

Date of sowing	Days to flowering	Plant dry weight at harvest (g $plant^{-1}$)	Grain yield (t ha^{-1})
17 Sep			
ICPL 151	75	6.4 cd[1]	1.1 bc
ICPL 332	94	13.7 a	1.5 a
LRG30	97	11.0 bc	1.3 ab
3 Oct			
ICPL 151	68	5.5 d	0.8 c
ICPL 332	84	11.3 ab	1.0 bc
LRG 30	87	9.0 a-d	0.9 c

1. Values within a column followed by the same letter do not differ significantly at the 0.05 level.

Prospects

Although pigeonpea is a minor pulse in Bangladesh, high-yielding SD and ESD varieties can play an important role in increasing the total pulse production. They hold great potential for growing in the fallow periods in existing cropping patterns of Bangladesh. They can also be grown in nontraditional cropping regions, such as the Chittagong hill tracts, where the land remains fallow during most of the year. There are many new cropping options for incorporating the SD and ESD pigeonpea types in the Chittagong region. In the hilly areas, an existing cropping pattern is rainy-season vegetables (brinjal, cucurbits, etc.), followed by fallow September-March; pigeonpea may be a potential crop for this fallow period. Another possibility is to grow pigeonpea as a border crop around the winter vegetable fields and also around aman rice fields, where it could be dibbled. This is a common practice for hyacinth bean *(Dolichos lablab)* in this region.

In the northern part of the country, one of the cropping patterns is aus rice-urd-fallow. In this cropping sequence, farmers do not grow postrainy-season crops because of lack of soil moisture at sowing time, but SD pigeonpea can be grown as a mixed crop with urd.

Strengthening of Future Research Program

ICRISAT has a strong program for pigeonpea research and is therefore in a position to provide substantial support on pigeonpea research in Bangladesh. To enhance adaptation and eventually adoption of pigeonpea in Bangladesh, it is necessary to

- Screen cold- and drought-tolerant lines in different agroclimatic conditions.
- Screen germplasm resistant to or tolerant of insects and diseases.
- Develop an improved package of cultural practices that includes suitable techniques to (1) minimize pod borer (M. *testulalis)* and phytophthora blight; (2) establish plant stand for higher yields under variable conditions; and (3) use rhizobial inoculation.
- Develop profitable technologies for intercropping, mixed cropping, and relay cropping with pigeonpea.
- Identify potential areas for growing pigeonpea in nontraditional regions.
- Extend the adaptation of ESD pigeonpea to hilly areas of Bangladesh.

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Prospects for Extra-short-duration Pigeon pea in Pakistan

A M Haqqani[1]

Introduction

In Pakistan, pigeonpea is cultivated on a very small scale. In 1972, the area under pigeonpea was 2000 ha, with a total production of 1000 t (Nene and Sheila 1990), but this reported area has declined further. Generally, pigeonpea is grown as a border crop around sugarcane, cotton, and groundnut. It is also cultivated as a sole crop on a small scale by a few farmers in Sialkot (Punjab), Peshawar (North-West Frontier Province, or NWFP) and Nawab Shah (Sindh).

Pigeonpea is consumed mainly in the rural and urban areas of Sindh Province, especially in Karachi and Hyderabad cities. It is cooked as *dhal* (dry grain dehulled and split into cotyledons) to make curry for eating with rice and chapati. Its green seeds are cooked as a vegetable and sometimes cooked with minced meat to make a delicious dish. The seed coats and pod shells are fed to cattle. When grown as a border crop, its leaves and pods are fed to goats.

After harvest, the dry stalks are an important source of household fuelwood for small farmers.

Pigeonpea Varieties

Local pigeonpea varieties are of long duration, giving low yields and low income per unit land used. Seeds of short-duration (SD) varieties were obtained from ICRISAT in 1990 for testing in Pakistan. In trials conducted at the National Agricultural Research Centre (NARC), Islamabad; the Agricultural Research Station at Dudhial (Mansehra); and the Pulses Research Station, Tandojam, the genotypes ICPL 87097, ICPL 87094, ICPL 151, and ICPL 86009 gave the highest grain yields at Dudhial (Table 1). ICPL 87094, ICPL 88009, and ICPL 87097 produced the highest grain yields at Tandojam (Sindh). ICPL 87098, ICPL 83015, ICPL 88007, and ICPL 87094 were highest yielding at NARC. On an average, ICPL 87094 and ICPL 87097 yielded the highest at all three locations, proving their wide adaptability.

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1. National Agricultural Research Center, Islamabad, Pakistan.

Haqqani, A.M. 1996. Prospects for extra-short-duration pigeonpea in Pakistan. Pages 50-52 *in* Prospects for growing extra-short-duration pigeonpea in rotation with winter crops: proceedings of the IARI/ICRISAT Workshop and Monitoring Tour, 16-18 Oct 1995, New Delhi, India (Laxman Singh, Chauhan, Y.S., Johansen, C., and Singh, S.P., eds.). New Delhi 110 012 and Patancheru 502 324, Andhra Pradesh, India: Indian Agricultural Research Institute and International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Grain yield of pigeonpea genotypes in diverse agroclimatic environments in Pakistan, 1990/91.

	Grain yield ($t\ ha^{-1}$)			
Genotype	Islamabad[1]	Dudhial	Tandojam	Mean
ICPL 4 (C)	0.9	2.8	0.9	1.6
ICPL 151	0.8	3.4	1.5	1.9
ICPL 83006	1.1	2.3	1.7	1.7
ICPL 83015	1.2	2.4	1.8	1.8
ICPL 84023	0.6	2.8	1.9	1.8
ICPL 85010	1.1	2.6	1.5	1.7
ICPL 85030	1.1	2.1	1.8	1.7
ICPL 86009	0.7	3.4	1.8	2.0
ICPL 87093	0.7	1.7	0.8	1.1
ICPL 87094	1.2	3.5	2.5	2.4
ICPL 87095	0.7	2.3	1.4	1.5
ICPL 87097	1.0	3.6	2.1	2.3
ICPL 87098	1.4	3.0	1.1	2.1
ICPL 88001	0.9	2.2	1.8	1.7
ICPL 88007	1.2	2.5	1.6	1.8
ICPL 88009	0.3	2.3	2.1	1.6

1. At the National Agricultural Research Centre.

Constraints to Pigeonpea Cultivation

Constraints to pigeonpea cultivation in Pakistan are

1. Pigeonpea dhal is not very popular in Pakistan-consumers do not like its taste and prefer other pulses.
2. No market exists for pigeonpea.
3. Research on this crop has been negligible; thus, no suitable high-yielding varieties are available to fit into existing cropping patterns.
4. Pigeonpea is traditionally a long-duration crop that gives low profits per unit land occupied.
5. There is a lack of agronomic information that would help expand pigeonpea cultivation in rainfed and irrigated areas.
6. Improved extra-short-duration (ESD) genotypes are not available to farmers.
7. Quality seed is difficult to produce; as pigeonpea is often cross-pollinated, considerable variability occurs in plant type and other characters in most seed lots.
8. Appropriate production technology is lacking.
9. Scientific and technical manpower to promote pigeonpea is lacking.

Collaboration with ICRISAT

To overcome some of the constraints to pigeonpea cultivation, the linkage between NARC and ICRISAT should be made strong and effective. ICRISAT should supply new, relatively dwarf, ESD varieties and hybrids for testing at national research stations located in diverse agroclimatic zones. In-service training and visits of senior scientists to ICRISAT would also increase trained manpower for pigeonpea research and development in Pakistan.

Future Prospects

Pigeonpea can simultaneously and satisfactorily meet the need for food, feed, and fuel. Although pigeonpea is not commonly used in Pakistan, except in the rural and urban areas of Sindh on a very small scale, it can be used in livestock feed as a cheap source of plant protein. Pigeonpea also has ameliorative effects on the soil in which it grows. It is a drought-resistant and very hardy crop, which grows well on marginal lands. Therefore, the potential for SD pigeonpea cultivation should be explored in the Pothohar region (Jhelum, Chakwal, Rawalpindi, and Attack districts), in Punjab (Sialkot, Gujranwala, Gujarat districts), in Sindh (Nawab Shah, Shakarpur, Larkana, Dadu, Sakkar, and Jacobabad districts), and in the NWFP (Peshawar district). It can also be grown successfully on the slopes of mountains in the NWFP and northern Punjab to reduce soil erosion, store rainwater in the soil profile, and also to meet the food needs of the people dwelling in those areas.

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Prospects for Short-duration Pigeonpea in Sri Lanka

K E Karunatilake[1], K B Saxena[2], K D S M Joseph[1], and K D A Perera[1]

Introduction

Sri Lanka, an island with a population of about 17 million and an area of 65 610 km^2, has a wide diversity of environmental conditions, which makes it suitable for the cultivation of a number of lowland and upland crops. Meteorologically, the country has been divided into wet (0.85 m ha), intermediate (1.52 m ha), and dry (4.17 m ha) zones. Cultivation of most pulse crops is confined to the dry zone (Fig. 1), which has a bimodal pattern of rainfall. The northeast and southwest monsoons determine the two cropping seasons, *maha* (Oct-Mar) and *yala* (Apr-Sep). Of these, maha is the major season, with an average rainfall of 1200 mm. February, March, June, July, and August are generally dry, with no rain or very little rain. Traditionally, under rainfed conditions, longer-duration crops and varieties are cultivated in maha; short-duration crops and varieties, in yala, either rainfed or with limited irrigation.

The dry-zone soils are mainly Alfisols, which have low water-holding capacity and harden quickly after rains. The noncalcic brown soils of the east coast are low in fertility, while the red-yellow Latosols in the northern peninsula are relatively more fertile, with high cropping intensity involving high-value crops.

Pulses play an important role in dryland crop production systems in Sri Lanka. The major cultivated pulse crops are cowpea, *Vigna unguiculata* (L.) Walp.; mung bean, *Vigna radiata* (L.) Wilczek; and urd, *Vigna mungo* (L.) Hepper. However, lentil *(Lens culinaris* Medic.) has become the most popular pulse. Because environmental conditions in Sri Lanka do not allow lentil cultivation, a huge amount of foreign exchange (US $ 30 million) is spent annually on importing lentil to meet the national requirements.

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Karunatilake, K.E., Saxena, K.B., Joseph, K.D.S.M., and Perera, K.D.A. 1996. Prospects for short-duration pigeonpea in Sri Lanka. Pages 53-61 *in* Prospects for growing extra-short-duration pigeonpea in rotation with winter crops: proceedings of the IARI/ICRISAT Workshop and Monitoring Tour, 16-18 Oct 1995, New Delhi, India (Laxman Singh, Chauhan, Y.S., Johansen, C., and Singh, S.P., eds.). New Delhi 110 012 and Patancheru 502 324, Andhra Pradesh, India: Indian Agricultural Research Institute and International Crops Research Institute for the Semi-Arid Tropics.

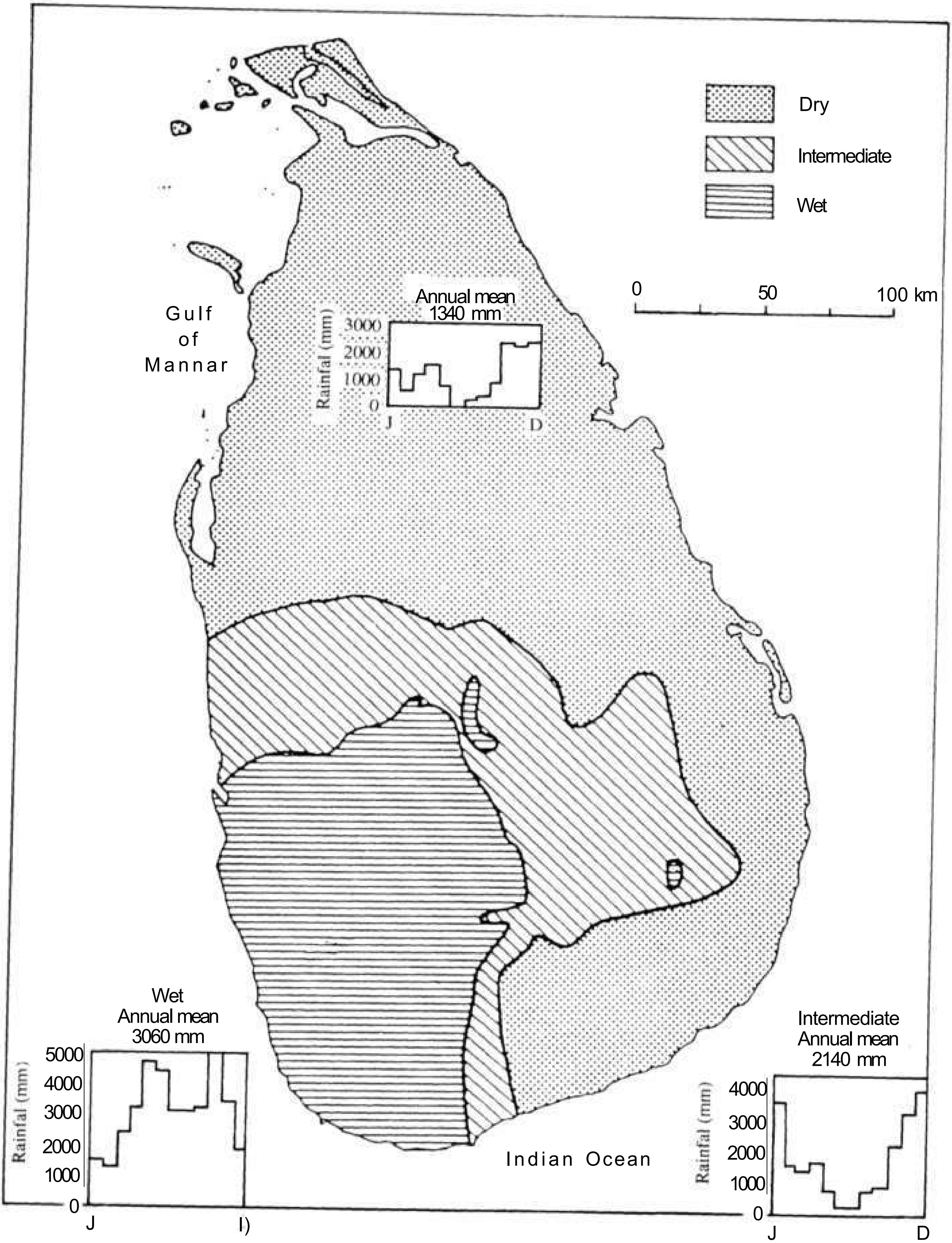

Figure 1. Climatic zones of Sri Lanka.

Early Pigeonpea Research and Development Activities

In Sri Lanka, pigeonpea research and development have experienced several ups and downs. In the past 40 years, there have been several attempts to intensify pigeonpea production; each, however, failed to take off due first to insect pests and practical difficulties in managing them at field level and second, to a lack of suitable processing techniques.

In the 1950s, tall, indeterminate varieties (T 64 and T 85) were promoted on a large scale, but *Helicoverpa armigera* caused the demise of the crop. Thereafter, a short-statured variety, MI 10, was developed in 1970. Pigeonpea yields reached an all-time high (1.3 t ha^{-1}) in 1974, but then the pod borer, *Maruca testulalis,* brought pigeonpea cultivation to a standstill.

New Production System

Using ICRISAT's short-duration (SD) pigeonpea genotypes, a new production system was evolved at the Field Crops Research and Development Institute (FCRDI), which exploits the bimodal rainfall pattern to take a ratoon crop of pigeonpea. The crop is sown in late October or early November, and maha-season rains help its establishment and growth. Harvesting is done during February-March. With the onset of yala rains in late March or early April, the already established maha-season crop is ratooned at a height of about 30-40 cm. This restricts plant height and induces new branches to grow from the stumps. The ratoon crop is harvested in June-July (Fig. 2). Since the ratoon crop flowers early, it has the added advantage of escaping drought and many insect pests.

New Initiatives

Efforts to promote the cultivation of pigeonpea in the past were nullified by the failure to overcome problems of insect pest damage, lack of knowledge of processing methods, and lack of suitable varieties. Considering these factors and recognizing the importance of pigeonpea in Sri Lanka, a project was initiated in October 1990, with financial assistance from the Asian Development Bank and technical assistance from ICRISAT. The main objectives of the project were to (1) provide the production technology needed to make pigeonpea available to consumers at an economic price and (2) strengthen the pigeonpea research structure in Sri Lanka to provide new technology for increased and sustainable pigeonpea production.

During Phase I of the project, field trials were conducted to demonstrate the pigeonpea production package developed by the Department of Agriculture. A total of 158 demonstrations, covering an area of 48 ha, were conducted in three dry-zone districts. Yields in all three districts were promising. Many farmers harvested more than 1 t ha^{-1} and some even 2 t ha^{-1}. The maximum yield recorded was 3.7 t ha^{-1} (0.4 ha area) in Kurunegala district. In addition, 17 demonstrations planted under

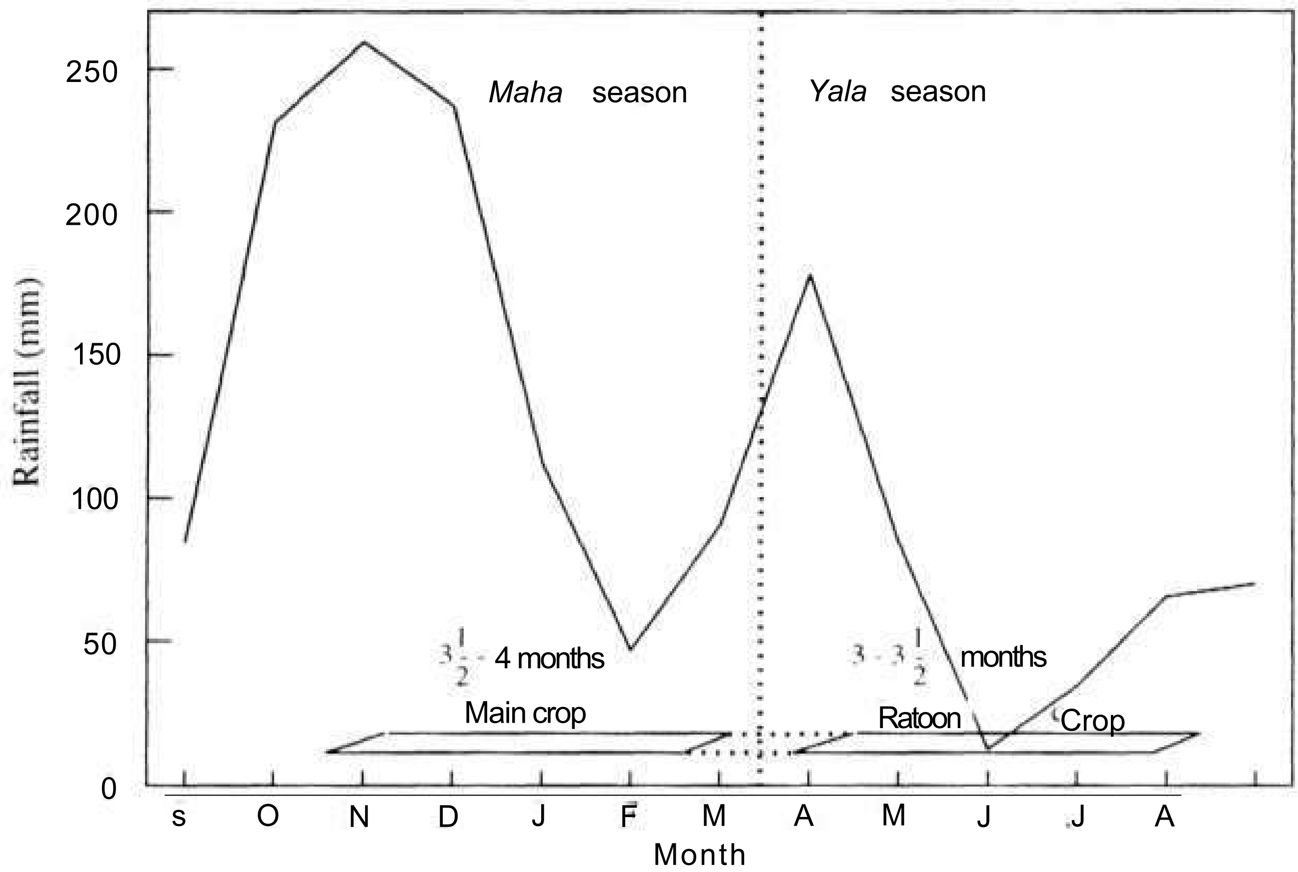

Figure 2. Rainfall distribution in the dry zone and pigeonpea production systems in Sri Lanka.

the People's Participation Program also gave promising results. The yield of ICPL 87 averaged 1.4 t ha^{-1} (7 demonstrations) and that of ICPL 2 averaged 1.2 t ha^{-1} (10 demonstrations). The highest yield (2.6 t ha^{-1}) was recorded in ICPL 87 in Konwewa village.

These on-farm demonstrations showed that rainfed pigeonpea can produce very good yields with three or four insecticide sprays. Studies showed that the average cost per hectare *of* pigeonpea cultivation was about Rs 18 370, and pesticides and labor accounted for the major expenditure (Fig. 3). The average profit per hectare was about Rs 6160; this high level of profitability indicated that pigeonpea should be able to compete very well with the traditionally grown pulse crops in Sri Lanka (Fig. 4).

For seed processing, two small-scale processing machines developed by the Central Food Technological Research Institute (CFTRI), Mysore, India, were imported. However, these machines were unsuitable, as they broke down frequently; thus the processing and marketing continued to be a serious constraint to the adoption of pigeonpea.

The pigeonpea research program is mainly concentrated at the FCRDI, in Maha Illuppallama. The main breeding objectives of the program are to develop high-yielding pigeonpea varieties with pod-borer tolerance and good ratoonability. To achieve this, advanced breeding lines were introduced from ICRISAT for evaluation. In Sri Lanka, the SD pigeonpea varieties, when planted in mid-October, are severely attacked by M. *testulalis.* The incidence of this pest is extremely high, and without proper chemical control, no yield is obtained, because the peak flowering period of

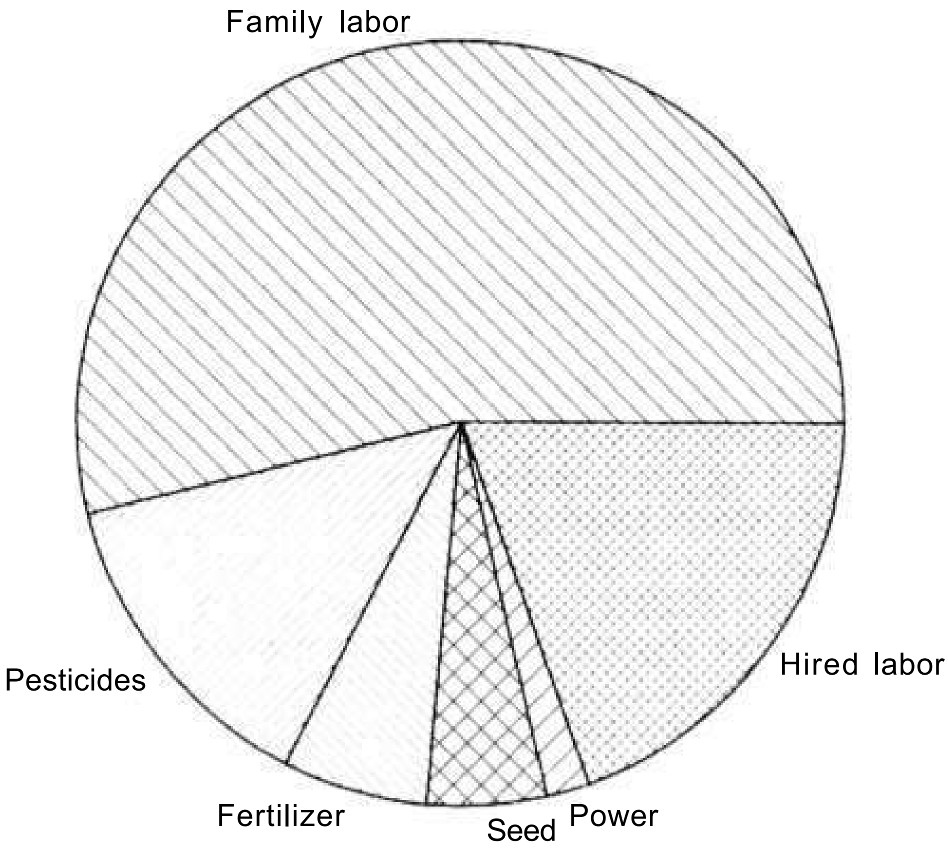

Figure 3. Average shares of major cost components in pigeonpea cultivation, Sri Lanka, maha season, 1990/91.

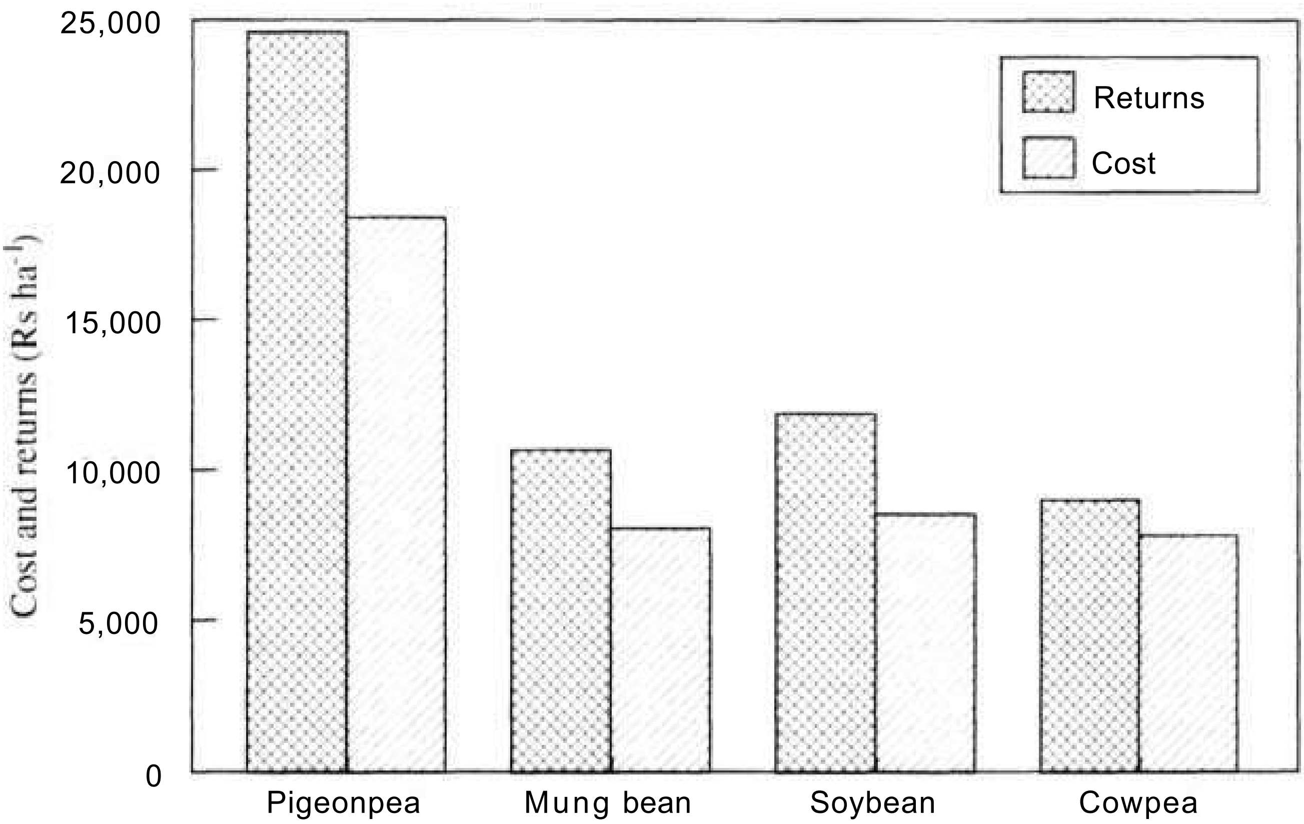

Figure 4. Production costs and returns (Rs ha^{-1}) from pigeonpea compared with three other legumes, Sri Lanka, 1990/91.

the SD types coincides with peak insect activity. The high natural incidence of *M. testulalis* has been used to screen germplasm to identify sources of resistance to or tolerance of this pest, and one line with tolerance, MPG 537, has been identified. This line is being evaluated in the integrated pest management and adaptability trials.

Present Status of Pigeonpea Research and Development

Encouraged with the results of Phase I of the project and considering the potential of pigeonpea in Sri Lanka, we started Phase II in 1994. From the experience gained during Phase I, processing was considered the most important constraint to the adoption of pigeonpea, and overcoming this problem was given first priority.

An engineer from the Department of Agriculture visited India to study the available processing machines. On his return, he designed and fabricated a prototype that gives 88 ± 2% recovery of high-quality *dhal.* At present, six such machines are in operation, and plans have been made to promote fabrication of the machines in the private sector. During the 1994/95 season, a number of field demonstrations of the machine were conducted, and almost all the produce obtained from 156 ha was processed and sold or consumed by farmers. Field demonstrations of processing and utilization will continue for another two or three seasons.

Other main research activities include identification of high-yielding genotypes through a series of station and multilocation trials. The agronomic aspects of research include determination of appropriate fertilizer recommendations, selection of appropriate herbicides, and intercropping of pigeonpea with maize, an important maha-season crop of the dry zone. Because insect pests are major production constraints, a fairly large proportion of research is devoted to (1) identifying effective and economical insecticides, (2) studying population dynamics of major pod borers, and (3) breeding for host-plant resistance to *M. testulalis.*

On-farm Research

On-farm research is a significant component of the pigeonpea research and development program in Sri Lanka. In the 1994/95 maha season, several trials were organized in farmers' fields to assess the potential of newly developed high-yielding lines and to test the new production system intercropping pigeonpea and maize.

Eight on-farm trials were conducted under rainfed conditions, using sole crops each of pigeonpea and maize and a maize/pigeonpea intercrop with a full population of maize and 50% of the recommended population of pigeonpea. Average yield reduction of maize due to intercropping was 14%, with a range of 5-23% in different on-farm trials (Table 1). In pigeonpea, average yield reduction was 51%. The gross returns from the intercrop combination provided Rs 9927 and Rs 7033 ha^{-1} additional income over the sole crops of maize and pigeonpea, respectively. The maize farmers are very enthusiastic about this new production system. The on-farm trials conducted

Table 1. Grain yield (t ha^{-1}) of maize and pigeonpea in sole crops and intercrops in eight on-farm trials in Sri Lanka, maha season 1994/95.

	Maize			Pigeonpea		
Location	Sole crop	Inter-crop	Yield reduction (%)	Sole crop	Inter-crop	Yield reduction (%)
Galenbindunawewa	6.3	4.8	23	0.8	0.4	43
Iththawewa	1.6	1.7	8	1.2	0.5	56
Mankadawala	4.8	4.5	5	1.5	1.0	37
Minneriya	2.2	2.0	10	1.0	0.5	53
Medirigiriya	2.4	2.0	15	1.1	1.0	11
Palagala	5.1	4.7	8	1.5	0.6	59
Vilachchiya - 1	5.7	4.4	21	1.8	0.4	78
Vilachchiya - 2	3.8	3.0	10	1.2	0.6	52
Average	4.0	3.4	14	1.3	0.6	51

Source: S.N. Jayawardhana, Field Crops Research and Development Institute (FCRDI), Maha Illuppallama, Sri Lanka (personal communication).

to identify the most adopted line for specific agroclimatic zones also gave promising results, with yields of 1-2 t ha^{-1}.

Studies on Integrated Pest Management

Experiments conducted at the FCRDI to evaluate the Maruca-tolerant line, MPG 537, under different spraying regimes showed that this line yielded three to four times more than ICPL 87 (Table 2). The extended rains made it difficult to control *M. testulalis* even after the recommended three sprays on ICPL 87. Results indicate that it should be possible to manage this pest with a combination of appropriate variety and insecticide. These results will be confirmed in on-station and on-farm trials during the 1995/96 season.

Commercial Production of Pigeonpea

In Phase I of the project, efforts to promote pigeonpea as a commercial crop did not meet with the expected success, and area under pigeonpea fluctuated around 70-150 ha, for the reasons discussed earlier. Therefore, in Phase II, special arrangements have been made to organize village-level processing and marketing channels. The pigeon-pea production program is supported by a fairly good seed production program in both the growing seasons. As a policy, the Government is encouraging farmers to grow, process, and consume pigeonpea, and to sell the excess in the market. The production program is also ably supported by food technologists to popularize,

Table 2. Effect of different insecticides on yield of Maruca-tolerant pigeonpea line MPG 537, Maha Illuppallama, Sri Lanka, maha season 1994/95.

Total number of sprays	Chemical	Yield (t ha^{-1})	
		ICPL 87[1]	MPG 537
0	Control	0.1	0.6
2	Chlorfluazuran (1) Thiodicarb (1)	0.2	1.1
2	Chlorfluazuran (1) Chlorpyrifos (1)	0.4	1.3
2	Chlorfluazuran (1) Etofenprox (1)	0.4	1.5
	Mean	0.4	1.3
3	Chlorfluazuran (1) Chlorpyrifos (2)	0.4	1.3
3	Chlorfluazuran (1) Thiodicarb (2)	0.2	1.8
	Mean	0.3	1.6

1. Control variety.

Source: Susanthi Chadrasena, Field Crops Research and Development Institute (FCRDI), Maha Illuppallama, Sri Lanka (personal communication).

through held demonstrations and training programs, various recipes using traditional ingredients.

Scope and Prospects

According to the data published by the Central Bank of Sri Lanka in 1992, about 91 648 ha of cultivable but uncultivated land exists in Sri Lanka. Research findings show that pigeonpea can be successfully grown on this land. The ratoon pigeonpea crop provides an additional income to dry-zone farmers during yala, when no other rainfed crop can be grown.

Besides providing a good income, pigeonpea production is also likely to generate employment. Economists have estimated that cultivation of 1000 ha of pigeonpea would provide employment equivalent to 187 000 labor days during the maha season, and if 50% of the cultivation is ratooned, another 15 000 labor days in the yala season. Therefore, considering the foreign exchange savings, agronomic advantages, food security/employment generation, and other social benefits, the national policy framework of the Ministry of Agriculture Land and Forestry has provided a firm commitment to promote pigeonpea production in the country. This policy framework also emphasizes progressively reducing the import of pulses, which will further help to promote pigeonpea cultivation.

Pigeonpea research and development activities in Sri Lanka now cover all the vital components: production, processing, marketing, and consumption. The results obtained so far are very encouraging. The adoption of SD pigeonpea, however, will depend on how effectively the farmers are able to increase their income and level of nutrition through the use of pigeonpea in the near future.

Enhancing Adaptation of Extra-short-duration Pigeonpea by Improving Plant Type

Y S Chauhan, C Johansen, and Laxman Singh[1]

Introduction

The term 'adaptation' generally refers to yield performance of a cultivar in one or more environments over time. Adaptation involves two related but distinct crop attributes: adaptability and stability. Adaptability represents yield variability across sites averaged over years; stability represents yield variability at a given site averaged over years. Farmers would be interested mainly in a stable cultivar at their own farm sites. Ideally, a crop improvement program, besides enhancing adaptability, should adequately consider increasing stability, especially for unpredictable abiotic and biotic constraints, such as erratic rainfall, insect pests, and diseases.

The major goals in developing extra-short-duration (ESD) pigeonpea cultivars at ICRISAT have indeed been to improve their adaptability to a broader range of environments as well as their stability in intensive cropping systems. A good degree of success has been achieved in enhancing the adaptation of ESD cultivars to different environments. The latest releases of ESD pigeonpea cultivars derived from ICRISAT-bred materials are in the USA, at 45° N latitude, in contrast to a limit of 30° N and S latitudes for medium- and long-duration cultivars. The environments in which ESD cultivars can now be grown therefore involve a broader range of soils, photoperiods, and temperatures than before. Very limited information, however, is available on the relative adaptation of different ESD cultivars to diverse climatic environments and on the specific plant characters that play a role in conferring such adaptation. In this paper, adaptation and the plant characters that seem important to it are discussed.

Yield Potential

The highest recorded yield from ESD pigeonpea (5.0 t ha^{-1}) is on experimental plots in Tifton, Georgia, USA, at 34° N (Gupta et al. 1991b). In India, the maximum recorded yields in some small-plot experiments are 4.0 t ha^{-1} at Hisar (29° N) (ICRI-

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SAT 1989) and 2.9 t ha^{-1} at Patancheru (17° N)(ICRISAT 1990). The greater yield potential in northern India is largely related to the profuse growth of ESD genotypes. The generally realized yield of the ESD genotypes in experimental plots in both northern and peninsular India is 1.0-2.0 t ha^{-1}. At appropriate plant populations, the yield potential and the generally realized yield of ESD pigeonpea compare well with those of short-duration (SD) cultivar UPAS 120 in these environments.

Phenological Adaptation

The ESD genotypes generally flower in <68 days and mature in <115 days in Patancheru environments (Gupta et al. 1989). Because they mature early, they tend to escape drought and the low temperatures of the following winter season during the reproductive phase.

Based on a systems approach, Vidyalakshmi et al. (1992) postulated that ESD pigeonpea could find a niche as a sole crop with seasonal rainfall of only about 500 mm. Further, ESD types need only about 1800 to 1900 degree (°C) days compared with the 2150 °C days that SD cultivars need; hence, the ESD genotypes can vacate fields 20-30 days earlier than SD ones, which allows timely sowing of wheat. A crop duration that extends into the period for wheat sowing is a major constraint to the widespread use of SD cultivars in rotation with wheat.

The time to flowering and time to maturity of ESD pigeonpea are the only characters for which genetic control is greater than that of environment or genotype x environment interaction (Y S Chauhan, D H Wallace, C Johansen, and Laxman Singh, unpublished data); hence, these can easily be manipulated genetically. Flowering of most ESD cultivars is relatively insensitive to photoperiod, within the photoperiods prevailing in northern India (Gupta et al. 1989). However, Gupta et al. (1989) reported that crop duration varied rather widely, from 109 to 162 days, across several northern Indian locations (Table 1). Some of this variation could be attributed to suboptimal temperatures during pod filling. Low available phosphorus levels (<2 mg kg^{-1} soil) in the soil are also known to delay time to flowering and maturity in pigeonpea (Chauhan et al. 1992). Damage by blister beetle (*Mylabris pustulata*) and pod borers (*Helicoverpa armigera* and *Maruca testulalis*) to the first flush of flowers and pods can extend time to maturity.

Table 1. Yield (t ha^{-1}) variation of two extra-short-duration pigeonpea genotypes across four locations in northern India.

		Location			
Genotype	Year	Delhi	Hisar	Faridkot	Sri Ganganagar
ICPL 83006	1987	1.6 (147)[1]	3.2(112)	2.5(152)	-
ICPL 85010	1988	1.3(147)	1.2(106)	2.0(139)	1.2(122)

1. Figures in parentheses show crop duration (days to maturity).

Yield Adaptability

Yield of ESD genotypes varied almost twofold across the three locations, Hisar, Delhi, and Faridkot, situated within a narrow range of latitude (Table 1). However, at each location, the yields were 1.0 t ha^{-1}. Time to maturity showed wide variation. The yield was highest at Hisar (3.2 t ha^{-1}), with least days to maturity, in 1987, and at Faridkot in 1988.

Extra-short-duration genotypes were also evaluated under the Extra-early Arhar Coordinated Trials (EXACT) series conducted under the All India Coordinated Pulses Improvement Project (AICPIP) in 1987 and 1988. In these trials, yields of ESD pigeonpea were 1.35-2.01 t ha^{-1} in the northwestern plains, about 1.0 t ha^{-1} in the northeastern hill, 0.9-1.0 t ha^{-1} in the central, and 1.05-1.88 t ha^{-1} in the peninsular zones (ICRISAT 1990). The yield variation across different zones is not only due to photoperiod, temperature, and soil type, but also rainfall and solar radiation. Although the incidence of insect pests and diseases is controlled in these trials, these factors also contribute to low realized yields in different environments.

Yield Stability

Yield stability across seasons

At the ICRISAT Cooperative Center at Hisar, grain yield of ICPL 83006 over 6 years, beginning 1983, ranged from 0 to 3.2 t ha^{-1} (Table 2), the highest yield being obtained in the severe drought year of 1987, albeit with irrigation. The crop failed completely in 1985, when the farm was inundated in a very wet August. Again in 1988, when rainfall was 56% higher than the longterm average, grain yield was 1.3 t ha^{-1}. Thus, the poor realization of yield potential of the genotype in some years was apparently attributable to excess rainfall and possibly accompanying low solar radiation.

Table 2. Variation in yield (t ha^{-1}) of extra-short-duration pigeonpea genotype ICPL 83006 and rainfall (mm) over six growing seasons, Hisar, Haryana, India.

Year	Yield	Rainfall (±% over the long term)
1983	2.3	456 (+2%)
1984	2.8	351 (-21%)
1985	0	456 (+2%, 45% in August)
1986	3.0	383 (-14%)
1987	3.2	205 (-83%)
1988	1.3	698 (+56%)

Source: Unpublished data from trials conducted at ICRISAT Cooperative Center, Hisar.

Yield stability across sowings

In northern India, sowing of pigeonpea commences, with irrigation, soon after the harvest of wheat in mid-April and continues until the onset of the monsoon, rainfed. Therefore, cultivars with wide flexibility with respect to sowing time are needed. In a split-plot experiment conducted at Hisar in the dry year of 1987, yields of ESD line ICPL 87094 varied little with sowing dates ranging from 1 May to 28 July, and its performance was similar to that of the SD genotype ICPL 151 (Table 3). However, in the excessively rainy season of 1988, when overall yields were low for both SD and ESD genotypes, the ESD ones yielded generally higher than ICPL 151 sown in early May and end of June. The yield reduction in both genotypes was probably because of the heavy rains. But the SD genotype was more vulnerable, probably because it had less time available for recovery before the onset of winter. In the latest sowing, at the end of July, yields of even the ESD genotype were very low.

Table 3. Effect of sowing date on yield (t ha^{-1}) of short- and extra-short-duratior pigeonpea genotypes during a very dry (1987) and an excessively wet (1988) rainy season, Hisar, Haryana, India.

	ICPL 151[1]		ICPL 87094[1]	
Sowing date	1987	1988	1987	1988
Early May	2.6	0.8	2.4	1.3
End Jun	3.1	1.3	4.4	2.0
End Jul	2.8	1.3	3.4	1.0

1. ICPL 151 = short-duration; ICPL 87094 = extra-short-duration genotype.

Source: ICRISAT (1989,1990).

Analysis of Adaptation

To identify cultivars better adapted to particular environments or with wide adaptation, a proper understanding is required of genotypic performance across environments, the effect of the environment, and the interaction between the two. Yield trials have so far been used to identify genotypes that give the highest yields in a particular environment. However, no systematic analysis of stability has been done using these data sets. To generate information on adaptation patterns of SD and ESD cultivars, a trial was conducted at three latitudes: Patancheru (17° N), Gwalior (26° N), and Hisar (29° N). Some salient findings of the study are summarized below.

- Genotype (G) explained 7%, environment (E) 72%, and G x E interaction, 21% of the total variation in yield.
- ESD genotypes ICPL 83015, ICPL 85014, and ICPL 87117 showed specific adaptation to the Hisar environment; ICPL 83006 and ICPL 83019, to the Gwalior environment.

- Time to flowering was the only character for which genetic contribution (42%) was higher than the contribution of environment (33%) and G x E interaction (25%). At any given location, more than 50% variation in yield was accounted for by time to flowering, with yield increasing with delayed flowering. However, a longer crop duration in any given environment did not necessarily result in higher yield than in those environments where duration was short.
- Grain yield across environments or across genotypes depended on biomass production. Therefore, genotypes that produced high biomass (either because of longer duration or inherent vigor) gave higher yields up to an optimum of 14 t ha^{-1}, beyond which, however, yields tended to be reduced. Similarly, yields were higher in environments that were conducive to higher biomass production. About 79% of biomass production was controlled by environment, whereas only about 8% was controlled by genotype and about 12% by G x E interaction.
- Interestingly, harvest index correlated negatively with yield across genotypes and had no correlation across environments. This has also been established in other studies (Chauhan et al. 1995). Harvest index was low in environments where biomass production was high. In the subtropical environment of Hisar, the biomass tended to be as high as 21 t ha^{-1}, whereas optimum biomass production for maximum yield was around 14 t ha^{-1} (Chauhan et al. 1995). Clearly, while very high biomass production in such environments may provide higher yield of stalks, which are used as fuelwood, it may reduce grain yield. Thus, for such environments, attempts should be made to select genotypes with a high harvest index. A significant negative relationship between biomass and harvest index across both environments and genotypes (r=0.80) suggests that harvest index could be improved to reduce biomass production.

In beans, Wallace and Enriquez (1980) improved harvest index and yield of a variety by crossing a genotype that had high biomass production with one that had a high harvest index. A similar approach needs to be adopted for ESD pigeonpea. Selection for high harvest index, apart from increasing yield, would reduce excessive vegetative growth.

Plant Types for Higher Yield

The foregoing suggests that yield of ESD genotypes depends on biomass production, at least up to an optimum. However, the fact that biomass production is largely controlled by environment or G x E interaction complicates breeding efforts to increase biomass. Nevertheless, there is some possibility of exploiting heterosis to enhance biomass (Chauhan et al. 1995). Agronomic manipulation of plant population and sowing dates have also been used to enhance biomass production (Chauhan 1990). However, apart from this, there has not been much success in improving rate of biomass accumulation in ESD genotypes, which is particularly slow in the juvenile phase of growth. Instability of yield is partly due to this, because environmental factors, such as temperature, radiation, rainfall and its distribution, and genotypic duration control about 80% of biomass production. There is a need to break the negative relationship between harvest index and biomass, as this will buffer for variation in biomass production.

The question of whether to develop determinate cultivars or indeterminate ones has long been debated. Gupta et al. (1991a) found no disadvantage of determinate over indeterminate types where the crop was unprotected from insect attack, but found some yield advantage under protected conditions, because insect pest control is easier in a uniform canopy of less height, such as that of determinate types.

Phenological stability is very important to the success of pigeonpea in pigeonpea-wheat rotations. Most SD and ESD genotypes vary greatly in time to maturity, which may be 150 days in subtropical conditions, especially when rainfall is heavy. This not only reduces pigeonpea yields because pod filling occurs in the cool autumn weather, but also reduces the following wheat crop yields by delaying sowing of wheat. It appears that high soil moisture promotes greater vegetative growth, to the detriment of reproductive development. Cultivars that set pods irrespective of weather conditions would ensure timely maturity.

One factor often ignored in ESD pigeonpea improvement is photoperiod sensitivity for dry matter partitioning, which is different from photoperiod sensitivity for flowering. In northern Indian environments, ESD genotypes, when sown before the longest day (Apr/May), pod sparsely, perhaps because of the adverse effect of long daylength on pod-set. This has been confirmed in a controlled photoperiod experiment, where a 16-h photoperiod reduced pod-set compared with the control (12-h photoperiod) (Y.S. Chauhan, unpublished data). This could also be the reason for the reversion sometimes observed from the reproductive phase to vegetative growth on the return of favorable conditions, e.g., onset of monsoon rains. However, this could be avoided if cultivars could be developed for photoperiod insensitivity for pod-set. More strategic research is needed on this aspect.

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Insect Pests of Short-duration Pigeonpea and Their Management: Current Status and Scope

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Introduction

With the development of short-duration (SD) pigeonpea genotypes (e.g., T 21, UPAS 120, Pant A 3, AL 15, ICPL 87, ICPL 151) the cultivation of pigeonpea has become popular in certain irrigated tracts of India, particularly in Haryana, Punjab, Rajasthan, and central and western Uttar Pradesh. However, the average yield of these genotypes is considerably lower (0.5-1.0 t ha^{-1}) than the potential yield (1.2-2.0 t ha^{-1}). Short-duration pigeonpea is normally cultivated on good soils, with irrigation, by progressive and resourceful farmers. Therefore, there is a greater possibility of realizing the full yield potential of SD pigeonpea than of medium-duration (MD) and long-duration (LD) pigeonpea varieties, which are grown rainfed on poor soils.

A major cause of poor yields is the array of insect pests that attack pigeonpea. Although pigeonpea is known to be infested by over 300 species of insects, only about a dozen are known to cause economic damage to SD pigeonpea (Table 1).

Crop Loss Assessment

The insect pests that infest SD pigeonpea vary across areas and seasons, and little information is available on the relative importance of the various pests in each major area. To quantify their importance and the extent of crop losses, therefore, regular surveys of farmers' fields are required over several years. ICRISAT quantified pod damage through field surveys made 1975-81 and recorded 44% pod damage in the north-west plain zone (NWPZ) (Punjab, Haryana, and Delhi), where SD pigeonpea genotypes are grown (Lateef and Reed 1983) (Table 2). At ICRISAT Center in Patancheru, peninsular India, mean pod damage was found to be 44.2%, mainly due to the lepidopteran pod borer, *Helicoverpa armigera* (Lateef and Reed 1983).

Based on field surveys in Kanpur district of Uttar Pradesh in 1992/93, it was found that total pod damage from insects varied from 7.6 to 31.0%, with an average of 26.4%.

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Lal, S.S., Yadava, C.P., and Ahmad, R. 1996. Insect pests of short-duration pigeonpea and their management: current status and scope. Pages 69-72 *in* Prospects for growing extra-short-duration pigeonpea in rotation with winter crops: proceedings of the IARI/ICRISAT Workshop and Monitoring Tour, 16-18 Oct 1995, New Delhi, India (Laxman Singh, Chauhan, Y.S., Johansen, C., and Singh, S.P., eds.). New Delhi 110 012 and Patancheru 502 324, Andhra Pradesh, India: Indian Agricultural Research Institute and International Crops Research Institute for the Semi-Arid Tropics.

Table 1. Insect pests of short- and extra-short-duration pigeonpea in India.

Common name	Scientific name	Crop stage damaged	Status
Galerucid beetle	*Luperodes* sp	Seedling	Minor
Thrips	*Caliothrips indicus* *Megalurothrips distalis*	Seedling, flowering Seedling	Minor
Ants	Unidentified	Seedling and vegetative	Minor
Jassids	*Ambrasca* sp	Vegetative	Minor
Leaf tier	*Grapholita (Cydia) critica*	Flowering and podding	Minor
Blister beetle	*Mylabris pustulata*	Flowering	Moderate
Spotted pod borer	*Maruca testulalis*	Flowering and podding	Moderate
Plume moth	*Exelastis atomosa*	Bud, flowering, and podding	Minor
Blue butterfly	*Lampides boeticus*	Bud, flowering, and podding	Moderate
Gram caterpillar	*Helicoverpa armigera*	Podding	Serious
Podfly	*Melanagromyza obtusa*	Podding	Moderate
Brown bug	*Clatrigralla gibbosa*	Podding	Moderate
Green bug	*Nezara viridula*	Podding	Minor
Bruchid	*Callosobruchus indicus*	Podding	Minor

Table 2. Pigeonpea pod damage by insects in samples from farmers' fields in India.

Zone (cultivar duration)[1]	Number of fields sampled	Pod damage (%)			
		Pod borers	Podfly	Pod wasp	Total
North-west Plain (SD)	49	29.7	14.5	0.03	44.0
Northern (LD)	359	13.2	20.8	0.05	33.8
Central (MD, LD)	446	24.3	22.3	1.06	48.0
Southern (SD, MD)	443	36.4	11.1	2.02	49.9

1. SD = short-duration; MD = medium-duration; LD = long-duration cultivar.

Source: Lateef and Reed 1983.

To quantify the relative distribution pattern of different insect species that infest flowers and pods of SD pigeonpea, insect samples were collected from farmers' fields in Kanpur district 1992/93-1994/95. In this area, *Grapholita (Eucosma) critica* is the most important pod borer, followed by *H. armigera, Maruca testulalis,* species of Lycaenidae, and *Exelastis atomosa.* Among the other insect pests, the brown bug, *Clavigralla gibbosa,* was the major one. The blister beetle was sporadic and localized.

Management Strategies

Little practical work has been done in India on the management of the pest complex infesting SD pigeonpea. Chemical insecticides found effective on MD and LD pigeonpea pests have been adopted on SD pigeonpea without considering the pest complex that occurs on early-maturing varieties. Therefore, the management of insect pests on SD pigeonpea has not been satisfactory. No systematic efforts have been made to identify the pest species occurring on SD pigeonpea, their relative importance, and their succession. Therefore, there is an urgent need to generate systematic information on the pest complex, the relative importance of different species, population buildup patterns, natural enemies, etc., before a scientific management strategy can be evolved.

Cultural control

There is a possibility of exploiting the phenomenon of host avoidance against some of the major insect species, provided detailed bio-ecological information is generated for each major agroecological zone. The role of trap crops can also be examined and such crops can be used in a limited way, mainly against *H. armigera* and M. *testulalis.*

Biological control

There is good scope for the use of nuclear polyhedrosis virus (NPV) and *Bacillus thuringiensis* (Bt.) against *H. armigera;* however, these biological pesticides will be of limited use where the pest complex includes other important pest species, such as *Grapholita, Maruca, Lampides, Melanagromyza,* etc. To control these, the populations of natural enemies should be encouraged by growing plants that will attract them. Reports on the use of African marigold, cowpea, sorghum, etc., are already available in the literature.

It has already been reported that neem *(Azadirachta indica)* seed kernel extract at 5% and other neem-based formulations available in the market, such as Repelin (10%), Nimbecidine (0.2%), and Achook (0.5%), are highly effective as antifeedants against lepidopteran pod borers, particularly H. *armigera.* Therefore, the use of neem-based formulations should be further evaluated and their efficacy against pigeonpea pests be worked out. Use of *karanj [Pongamia glabra)* seed against *H. armigera* has also been reported to be effective, and therefore needs to be evaluated against the pest complex infesting SD pigeonpea.

Host-plant resistance

Several LD pigeonpea selections resistant to the podfly, *Melanagromyza obtusa,* have been identified at the Indian Institute for Pulses Research (IIPR) in Kanpur, Uttar

Pradesh, and PDA 88-2E and PDA 89-2E have been identified for use as sources of resistance in breeding programs. Similarly, some pigeonpea selections have been identified that are less damaged by *H. armigera* at ICRISAT, and the SD pigeonpea ICPL 86012 is reported promising. So far, no work on host-plant resistance (HPR) has been undertaken against *Maruca testulalis,* which is a key pod borer in central and southern India, or against *G. critica,* which has become a major pod borer in northern India. Therefore, there is an urgent need to initiate HPR work against major insect species infesting SD pigeonpea. The work done in India so far has been mainly confined to medium- and late-maturing pigeonpea.

Chemical control

Several insecticides, such as endosulfan, chlorpyrifos, quinalphos, monocrotophos, dimethoate, fenvalerate, cypermethrin, methomyl, and phosalone, have been reported to control flower- and pod-infesting insect species, but mainly on MD and LD pigeonpea, grown under dryland conditions. Little field evaluation has been done of the use of systemic insecticides on the pests infesting SD pigeonpea in various agroecological zones. Because pest complexes vary greatly across areas and seasons, it is necessary to systematically evaluate available insecticides and identify those that are not only most effective against the pest species but are least disruptive of the natural enemies.

Conclusion

Generating information on different components of pest management will make it possible to evolve an integrated approach, using cultural and biological methods, HPR, and ecofriendly insecticides to control the insect pests of SD pigeonpea. However, this can become a reality only when an aggressive research and development program, covering the major agroecological niches, is undertaken.

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Disease and Nematode Problems of Extra-short-duration Pigeonpea and Their Management

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Diseases of Extra-short-duration Pigeonpea

Major problems

In the traditionally cultivated medium-duration (MD) and long-duration (LD) pigeonpea, fusarium wilt *(Fusarium udum* Butler) and sterility mosaic disease (SMD) are the major disease problems in Asia. When extra-short-duration (ESD) pigeonpea genotypes are grown in these traditional areas, they also suffer from the same diseases. But the disease intensity differs, because of the different agronomic practices used for ESD genotypes, and the different phenological development of the crop. For example, in Asia, ESD pigeonpea has been found to suffer more from phytophthora blight (PB), *Phytophthora drechsleri* Tucker f.sp. *cajani* (Pal et al.), than the MD and LD types, in which it is a minor problem. The higher incidence of blight in the ESD types seems to be due to the higher plant populations and the rapid canopy development, which result in higher humidity.

Other diseases from which ESD pigeonpea suffers more than the other types are

1. Cercospora leaf spot (CLS), *Cercospora cajani* Hennings, especially in southern and eastern Africa, because flowering coincides with cool, humid weather, which favors the development of the pathogen.
2. Rhizoctonia dry root rot (DRR), *Rhizoctonia bataticola* (Taub.) Butler, especially when sown in the postrainy season on Vertisols in peninsular India, because of the high soil temperatures at reproductive stage.
3. Colletotrichum stem blight (CSB), *Colletotrichum truncatum* (Schw.) Andrus & Moore, bacterial leaf spot and stem canker (BLSSC), *Xanthomonas campestris* pv *cajani* (Kulkarni et al.) Dye et al., and macrophomina stem canker (MSC), *Macrophomina phaseolina* (Tassi) Goid., are found to affect ESD pigeonpea in the rainy season in the Vertisol belt of central India.

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However, ESD pigeonpea types suffer less from wilt than MD and LD types, as their growth period is too short for the disease to develop (Reddy et al. 1988). When the ESD types are grown in nontraditional areas, such as the USA or South Korea, they should be closely monitored for disease problems that may arise. In such temperate regions, ESD pigeonpea is likely to suffer more from foliar diseases, such as CLS and powdery mildew (PM), than in tropical climates.

Available management options

1. For wilt and SMD in traditional pigeonpea areas, such as India, Nepal, and Myanmar, quite a few ESD lines with combined resistance to both diseases are available (Table 1); in problem areas, as the first option, these can be tested in farmers' fields.
2. A few ESD lines, such as ICPL 83024 and ICPL 84023, with field tolerance of wilt, SMD, and PB, are available; these, too, need to be tried in farmers' fields.
3. Sources of tolerance for DRR, CLS, PM, and BLSSC, mainly in the MD and LD background, are available and can be utilized to develop ESD pigeonpea varieties with tolerance of these diseases.

   DRR: ICPL 86005, ICPL 86020, ICPL 87105, ICPL 91028 (Reddy et al. 1993a);

   PM: ICP 3940, ICP 7185, ICP 8131, ICP 8858, ICP 8859, ICP 8860, ICP 8861, ICP 8862, ICP 8869, ICP 9137, ICP 9140, ICP 9142, ICP 9146,

Table 1. Some short-duration pigeonpea lines with combined resistance to sterility mosaic disease (SMD) and wilt developed at ICRISAT Asia Center.

		Incidence in disease nursery during 1993	
Genotype	Growth habit	Wilt (%)	SMD (%)
ICPL 93175	Determinate	3.7	0.7
ICPL 93176	Determinate	12.3	4.4
ICPL 93177	Determinate	4.9	0.0
ICPL 93178	Determinate	8.3	4.5
ICPL 93179	Determinate	5.5	0.0
ICPL 93180	Determinate	7.5	4.4
ICPL 83181	Indeterminate	11.3	2.3
ICPL 83182	Indeterminate	8.4	5.3
ICPL 83183	Indeterminate	9.7	7.2
ICPL 93184	Indeterminate	9.5	3.7
ICPL 93185	Indeterminate	18.9	1.2
ICPL 93186	Indeterminate	14.3	5.0
Control			
ICP 2376	Indeterminate	95	0.0
ICP 8863	Indeterminate	5	100.0

ICP 9148, ICP 9149, ICP 9150, ICP 9152, ICP 9153, ICP 9154, ICP 9157, ICP 9158, ICP 9164, ICP 9166, ICP 9177, ICP 9179, ICP 9188, ICP 9189, ICP 9192, ICP 12732, ICP 12738, ICP 12740, ICP 12749, ICPL 136, ICPL 137, ICPL 171, ICPL 271, ICPL 171, and C 322 are early types (Raju 1988). ICP 7035, ICP 12972, and LRG 30 (Kannaiyan and Haciwa 1990), ICP 9150, ICP 13107, ICP 13156, ICP 13232 (Reddy et al. 1993b);

CLS: UC 796/1, UC 2568/1, UC 2515/2, UC 2113/1 (Onim and Rubaihayo 1976), ICP 8869, ICP 12792, and ICP 12165 (Kannaiyan and Haciwa 1990), 657/1, ALPL 6-2, 66 and *666* (Songa 1991);

BLSSC: ICP 12807, ICP 12848, ICP 12849, ICP 12937, ICP 13051, ICP 13116, and ICP 13148 (Reddy et al. 1987).

4. A 3-year rotation of ESD pigeonpea with other crops will be useful for reducing wilt inoculum and breaking the SMD cycle.
5. The combined use of a tolerant cultivar (e.g., ICPL 84023); seed-dressing with metalaxyl (Ridomil®); broadbed and furrows, or ridges; intercropping with fast-growing crops, such as urd; and one to three foliar sprays of Ridomil®/Ridomil MZ® at 15 days after sowing (depending on disease severity) will reduce PB. However, use of foliar sprays may not be economical.
6. For PM, CLS, and BLSSC, some fungicides/antibiotics have been reported to be effective (Bayleton® for PM, Benlate® and Dithane M-45® for CLS, streptocyclin for BLSSC); however, their use may not be economical.
7. Timing pigeonpea sowing so that flowering does not coincide with high soil temperatures (above 30° C) will be helpful in reducing DRR.

Recommendations for future research

Future research on diseases of ESD pigeonpea should focus on the following:

1. Survey of the existing ESD pigeonpea production areas in Asia and southern and eastern Africa for proper assessment of the prevalent diseases and the losses they cause.
2. Close watch for the potential disease problems that may arise in nontraditional pigeonpea areas, such as Sri Lanka, West Africa, and the USA.
3. On-farm evaluation in India and Nepal of the available lines resistant to or tolerant of wilt, SMD, and PB: ICPL 83024 and ICPL 84023 (Table 1).
4. Transfer of PB resistance from *Atylosia platycarpus* (Accessions #61 and 67) into ESD pigeonpea lines already resistant to wilt and SMD.
5. Confirmation of resistance to CLS, PM, DRR, and BLSSC through screening of known resistant lines at hot-spot locations and in laboratory /greenhouse tests and transfer of the resistance into ESD pigeonpea lines.
6. Identification of ESD pigeonpea lines with resistance to wilt in a ratoon system, wherever applicable.
7. Identification of components of integrated disease management (IDM) for foliar diseases, such as PB, CLS, and PM.

Nematodes

Major problems

Root-knot, cyst, reniform, and lesion nematodes are fairly widespread in northern India; some of the important ones known in wheat-based cropping systems targeted for introduction of ESD pigeonpea are discussed below.

Cyst nematodes

About 10 species of cyst nematodes have been reported from northern India. *Heterodera avenae,* the cereal cyst nematode, has been a major constraint in the wheat belt (Table 2). *H. cajani,* the pigeonpea cyst nematode, is an important constraint to pigeonpea, cowpea, mung bean, and urd (Sharma and Varaprasad 1995). In nematicidal trials, it has been estimated to cause yield losses of 25-80%. The maize cyst nematode, *H. zeae,* is also fairly well distributed in northern India. It can cause yield losses ranging from 12 to 26% in sandy loam soils. The differential reactions observed in maize and vetiver indicate the presence of pathotypes in the maize cyst nematode.

Table 2. Distribution of cereal cyst nematode in India.

State	District
Delhi	Najafgarh Block
Haryana	Ambala, Bhiwani, Gurgaon, Mohendergarh, Rohtak, Sirsa, Sonepat
Himachal Pradesh	Kangra, Una
Jammu and Kashmir	Leh area in Ladakh
Punjab	Bhatinda, Faridkot, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Patiala, Sangrur
Rajasthan	Ajmer, Alwar, Bhilwara, Jaipur, Jhunjhunu, Pali, Sirohi, Udaipur
Uttar Pradesh	Aligarh, Badaun, Ghaziabad

Source: Kaushal 1995.

Root-knot nematodes

Twelve species of the genus *Meloidogyne* are reported from India. The most widely prevalent are *M. incognita* and *M. javanica;* together with *M. armaria* and *M. hapla,* they cause yield losses to a wide range of crops. In Gujarat, tobacco is grown in rotation with wheat; M. *javanica,* which infests tobacco in this area, could infest wheat as well under such a cropping system. *M. javanica* is otherwise not a problem on wheat. In Orissa, wheat is severely infested by *M. graminis,* and *M. graminicola* is a constraint to rice production in northeastern India. Both nematodes could become problems in both crops in wheat-rice rotations. In parts of Uttar Pradesh and Gujarat, *M. incognita* and *M. javanica* reduce pigeonpea yields alone and in combination with *F. udum* (wilt).

Reniform nematodes

The reniform nematode, *Rotylenchulus reniformis,* is widely prevalent in vegetable, pulse, fruit (grape), fiber (cotton), and oilseed (castor) crops. It causes significant yield losses in pigeonpea. However, with cereals such as wheat and rice in the rotation scheme, nematode populations can be reduced to levels below the economic threshold.

Lesion nematodes

About 40 species of lesion nematodes are reported from India, of which *Pratylenchus coffeae, P. indicus, P. zeae,* and *P. thornei* are important. *P. coffeae* has a wide host range; currently important in southern India on coffee, it is also reported on groundnut and chrysanthemum from northern parts. *P. indicus,* a pest of rice, causes yield losses in parts of Assam, Gujarat, Kerala, Orissa, and West Bengal. Wheat, sorghum, and pearl millet are also hosts of *P. indicus.*

Management options

- Application of carbofuran, phorate, diazinon, or aldicarb at 1-2 kg a.i. ha^{-1} is very effective in increasing crop yields and reducing postharvest nematode populations. Fumigant nematicides, though highly effective in controlling nematodes, are not popular, because of the cumbersome methods of application and expense; they are also not easily available.
- Resistant sources have been identified for root-knot and cyst nematodes. Resistant varieties of tomato and potato have been released for cultivation in problem areas. However, progress is rather slow in other crops. A Turkish wheat genotype, AUS 15854, resistant to several populations of cereal cyst nematode in northern India, has been identified, and breeding programs are under way using it as donor parent for incorporating resistance into high-yielding varieties.
- Application of organic soil amendments, such as neem cake, mustard cake, etc., are known to increase natural enemies in the soil ecosystem and reduce nematode populations considerably.
- Deep plowing in summer, exposing nematodes to harsh weather (high temperature and low humidity), reduces cereal cyst nematode populations in northwestern India and increases subsequent wheat yields.

- Crop rotation can be an effective method of controlling nematodes. It has been observed that damage from the pigeonpea cyst nematode is less severe in pigeonpea/sorghum mixed crops than in pigeonpea/urd or /mung bean. It has also been shown that growing of gram, mustard, carrot, fenugreek, or onion in rotation with wheat reduced cereal cyst nematode populations to about 50% and doubled wheat yields after 2 years of rotation.
- Biological agents that attack nematodes, such as *Catenaria vermicola, Verticillium uniseptum, Paecylomyces lilacinus,* and the bacterium *Pasteuria penetrans,* have been identified, and *P. lilacinus* and *P. penetrans* are being tried on a field scale for control of root-knot and cyst nematodes. .

Future research plans

The distribution of nematodes needs to be mapped in detail (district level), with specific reference to wheat-based cropping systems. Nematode population dynamics and the effect of nematodes on each component of the cropping system should be studied, especially in areas where new crops and plant types are introduced. Advisory programs based on initial population levels need to be developed for wheat-based cropping systems, with due emphasis on nonchemical methods of nematode management to keep the populations below economic threshold levels in areas where nematodes are endemic.

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Abiotic Stresses of Extra-short-duration Pigeon pea

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Introduction

Extra-short-duration (ESD) pigeonpea genotypes that can mature in 90-110 days have been recently developed (Laxman Singh et al. 1990). They are suitable for intensive cultivation as sole crops and have been tested for adaptation to rainfed semi-arid environments (Chauhan et al. 1993). In some situations, they are capable of producing higher yields than medium-duration (MD) genotypes, because their duration better matches the length of the growing season, and they escape terminal drought stress (Chauhan 1990). However, although the ESD genotypes have good yield potential (up to 3 t ha^{-1}), its realization varies with the soil moisture status, to which these genotypes are very sensitive. This paper summarizes our present knowledge of the major abiotic constraints to the production of ESD pigeonpea and discusses strategies for their alleviation.

Drought

Drought is a major factor limiting the realization of high yields in pigeonpea. Extra-short-duration genotypes escape terminal drought and have therefore shown good adaptation to environments with a short growing season (3-4 months). They have, however, shown sensitivity to intermittent drought (Nam 1994). Intermittent drought coinciding with the flowering and early pod-filling stages causes the most yield reduction; drought at preflowering and pod-filling stages, the second most (Nam 1994). Among the few genotypes tested so far, ICPL 88039 has been found to be the best adapted to intermittent drought coinciding with the flowering stage. ICPL 88032, which yielded more (2.5 t ha^{-1}) than ICPL 88039 (1.93 t ha^{-1}) under irrigation, yielded 23% less than ICPL 88039 when intermittent drought stress occurred at flowering stage. This suggests that environments need to be characterized for possible periods of stress in order to maximize yields of different genotypes. A few genotypes,

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such as ICPL 84023, performed well irrespective of the stage at which stress occurred (Nam 1994).

Waterlogging

Waterlogging has been recognized as one of the major constraints affecting stability of production in most regions in India where pigeonpea is grown (Reddy and Virmani 1981). Pigeonpea is highly sensitive to waterlogging, which could result in considerable loss in crop vigor and stand (Chauhan 1987). Further, susceptibility to waterlogging predisposes pigeonpea to phytophthora blight. The susceptibility of ESD pigeonpea to waterlogging is a major concern, as the crop has little time to recover from it and in subtropical environments, its growth is likely to extend into cooler, unfavorable periods. The yields of ESD pigeonpea on Vertisols prone to waterlogging are generally half of those that can be obtained on well-drained Alfisols (Chauhan et al. 1993). Nitrogen fixation of a short-duration pigeonpea, ICPL 87, is considerably reduced by anaerobic conditions in Vertisols, which is one reason why yield responses to nitrogen fertilizer are obtained on these soils (Kumar Rao 1990; Matsunaga et al. 1994).

Using the pot screening method developed at ICRISAT (ICR1SAT 1992), we screened many pigeonpea genotypes of different maturity groups and found genotypic differences in their tolerance of waterlogging (Table 1). Some of the ESD genotypes, e.g., ICPL 84023 and ICPL 93072, which are tolerant of waterlogging, could grow and produce seed in pots. Further studies are needed to confirm the performance of waterlogging-tolerant lines under field conditions. Nam (1994) reported yield losses of up to 40% due to waterlogging in ESD pigeonpea and also considerable genotypic differences in response to timing of waterlogging, although only a few genotypes were tested.

Until we have more information in this area, agronomic management of waterlogging in pigeonpea is best done by growing the crop in well-drained fields, either on ridges or in broadbeds with furrows. Yields were higher when pigeonpea was grown on ridges than in flat beds, because of improved soil aeration (ICRISAT 1989).

Another management option to alleviate waterlogging effects on ESD pigeonpea is to topdress with nitrogen. Matsunaga et al. (1994) reported that topdressing of N at 50 kg ha^{-1}, soon after waterlogging stress, alleviated damage in a short-duration pigeonpea, as shown by final yields. Similar studies are needed to work out appropriate rates of N fertilizer for ESD pigeonpea.

Solar Radiation

The level of solar radiation may limit performance of ESD pigeonpea genotypes, which usually flower during the rainy season, when light levels are low. More studies are needed to determine whether the low light levels affect flowering and yields of ESD pigeonpea; if so, to what extent.

Table 1. Effect of waterlogging for 8 days on plant survival and total plant dry matter of extra-short-duration pigeonpea genotypes, ICRISAT Asia Center[1].

Genotype	Plant survival (%)[2]		Total plant dry mass (g plant^{-1})		
	Control	Waterlogged	Control	Water-logged	Loss (%) due to waterlogging
ICPL 84023	100(90)3	83 (70)	3.01	2.15	28.0
ICPL 85010	100(90)	100 (90)	2.93	1.82	37.4
ICPL 85012	100(90)	92 (80)	2.69	1.51	43.9
ICPL 86023	100(90)	67 (60)	2.30	1.61	29.8
ICPL 87095	100(90)	100 (90)	2.67	1.40	46.7
ICPL 88009	100(90)	17(20)	4.68	2.75	39.8
ICPL 88039	100(90)	100 (90)	3.06	1.76	42.3
ICPL 91002	100(90)	100 (90)	2.48	1.37	44.9
ICPL 91031	100(90)	100 (90)	2.19	1.75	19.2
ICPL 93072	100(90)	100 (90)	2.00	1.57	20.4
ICPL 93074	100 (90)	100 (90)	2.57	1.56	38.8
Prabhat	100(90)	83 (70)	2.44	1.63	32.5
ICP 14199 (Tolerant control)	100(90)	100 (90)	1.72	1.40	18.4
ICP 7035 (Susceptible control)	100(90)	0 (0)	2.41	1.84	23.6
ICPL 86012 (Susceptible control)	100(90)	0 (0)	4.36	2.59	40.3

1. Forty-two-day-old plants grown in the greenhouse in pots containing a Vertisol.
2. Mean of 3 replications, each with 4 plants pot^{-1}.
3. Values in parentheses are after angular transformation.

Photoperiod and Temperature

Pigeonpea is a quantitative short-day plant. The ESD genotypes, however, have a long critical daylength (14 h). The rates of progress from sowing to flowering (1/f) are therefore mostly unaffected by, but sometimes slightly responsive to, photoperiod (Omanga et al. 1995). However, ESD genotypes respond very strongly to mean temperatures below and above an optimum value close to 24°C for flowering (Omanga et al. 1995). In the suboptimal range, the effects are positive and in the supraoptimal range, they are negative. At higher latitudes, as in northern India, the longer days prevailing during summer months (Apr-Jul) can combine with supraoptimal temperatures to delay flowering and maturity of ESD genotypes. This could be why ESD genotypes take longer to flower in northern India than at lower latitudes in peninsular India (Gupta et al. 1989).

Nutrition

In India, the most important nutrient deficiency affecting pigeonpea is that of P, followed by Zn and N (Johansen 1990). Low P levels (<5 mg kg^{-1}) have been found to delay flowering and maturity in SD pigeonpea (Chauhan et al. 1992). To what extent the yield of ESD genotypes is affected by deficiency of these nutrients is not yet established. These deficiencies are best overcome by addition of appropriate fertilizers and soil amendments. The role of biofertilizers *(Rhizobia,* vesicular-arbuscular mycorrhizae, phosphate solubilizers, and other beneficial microorganisms), either alone or in combination with inorganic fertilizers, in meeting the nutrient requirements of ESD pigeonpea also needs to be studied.

Johansen (1990) reported that pigeonpea, like other legumes, is adversely affected by soil conditions such as salinity and acidity. Johansen et al. (1990) reported that half-maximal growth of 40- to 45-day-old seedlings of a range of pigeonpea genotypes growing in sand or solution culture occurred at 5-7 dS m^{-1}. In a saline Vertisol, this critical range corresponded to 1.5-3 dS m^{-1} in a 1:2 soil-water extract. Cultivated pigeonpea genotypes show little variation in salinity tolerance. Subba Rao et al. (1991) have demonstrated sources of substantial salinity tolerance among wild relatives of pigeonpea, *Cajanus (Atylosia) platycarpus* and C. *albicans.* These species can grow, flower, and set pods at 10 dS m^{-1} and thus offer the extent of salinity tolerance needed for significant genetic enhancement in cultivated pigeonpea. Only *C. albicans* readily crosses with cultivated pigeonpea, and the F_1 hybrids of such a cross exhibit the level of salinity tolerance of the tolerant wild parent, indicating that this trait is genetically dominant (Subba Rao et al. 1990).

Although pigeonpea can grow and fix N_2 in acid soils of pH range 4.5-5.5 (Edwards 1981; Abruna et al. 1984), it cannot below pH 4 (Chong et al. 1987). Liming can alleviate acid soil effects, but high rates of lime (e.g., 5 t ha^{-1}) may induce Zn deficiency (Dalai and Quilt 1977; Edwards 1981). The adverse effect of acidity on pigeonpea can be attributed to Ca deficiency and also Al toxicity. Narayanan and Syamala (1990) reported that in solution culture, 20 mg kg^{-1} Al was determined as a critical level for pigeonpea, with root growth becoming distorted at higher concentrations. They also reported genotypic differences in pigeonpea response to Al. Before we embark on research to determine sources of tolerance of salinity and acidity, we need to know whether these ESD genotypes are limited by salinity and acidity in northern India.

Conclusion

Extra-short-duration pigeonpea genotypes that can mature in 90-110 days are a relatively new plant type. They can yield well in environments with short (3-4 months) growing seasons, where they can escape terminal drought. However, they are sensitive to intermittent drought and waterlogging. Strategies involving both genetic and management options have been suggested for the alleviation of these abiotic stresses. The effects of various other abiotic factors-solar radiation, photoperiod, temperature, nutrients, salinity, and acidity-on ESD pigeonpea need to be studied in detail to assess their importance before research is planned to alleviate them.

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Prospects for Varietal Improvement in Extra-short-duration Pigeon pea

S P Singh[1]

Short-duration (SD) varieties of pigeonpea for use in multiple-cropping systems are a fairly recent development. Before 1970, almost all the area under pigeonpea in India was occupied by traditional medium-duration (MD) (200 days) and long-duration (LD) (300 days) types, which were generally grown in rainfed mixed crops, with minimal agronomic input.

Although variability for early maturity was reported as early as 1920, little effort was made before the inception of the All India Coordinated Pulses Improvement Project (AICPIP) to develop short-duration varieties for use in multiple-cropping systems. The first variety in this series, T 21, was developed at Kanpur (Uttar Pradesh) in 1961. However, the variety was not widely adopted until 1970.

Considering the importance of early maturity, a separate trial set, Arhar Coordinated Trial (ACT-1), was constituted for the first time under the AICPIP during 1968/69 (Ramanujam and Singh 1981). But only two other identified varieties, Khargone 2 (Madhya Pradesh) and BR 183 (Bihar) of 150 days' duration were available for testing in ACT-1 at that time; hence, the ACT-1 trial included both SD and MD entries.

After the inception of the AICPIP, Pusa Ageti was the first early variety recommended for commercial cultivation by the Indian Agricultural Research Institute (IARI) in 1971. This variety had more compact plants and bolder seed than T 21.

Although varieties of 150 days' duration were recommended for double-cropping in rotation with wheat in the north-west plain zone (NWPZ), their duration was still too long to fit well into the system. Further efforts were made to develop extra-short-duration (ESD) varieties, and such important varieties as Prabhat and UPAS 120, which served as archetypes for the Extra-early Arhar Coordinated Trials (EXACT) group (120-140 days), became available in 1972/73.

The development of these varieties revolutionized the cultivation of pigeonpea, enabling its sole-cropping, in rotation with wheat, in the states of Haryana, Punjab, Rajasthan, and western Uttar Pradesh. Replacing the traditional LD varieties that had occupied the total pigeonpea area until 1970, the ESD varieties dramatically increased yields and production during the period 1970-90 (Table 1).

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Table 1. Area, production, and yields of pigeonpea in four northwestern states of India, 1970-90.

	1970/71			1990/91			Increase/decrease (%)		
State	Area (ha)	Production (t)	Yield (t ha^{-1})	Area (ha)	Production (t)	Yield (t ha^{-1})	Area (ha)	Production (t)	Yield (t ha^{-1})
Haryana	8 900	4 240	0.5	52 325	49 613	0.9	488	1 070	99
Punjab	2 963	1 165	0.4	13 600	11200	0.8	359	861	109
Rajasthan	25 344	13 311	0.5	37 409	25 217	0.7	47	89	28
Uttar Pradesh	588 598	663 015	1.1	468 080	591 939	1.3	(-20)	(-11)	12

Source: Agricultural Situation in India. (Various years.)

The declining trends in area and production of pigeonpea in Uttar Pradesh are because only 15% of the total area grows SD or ESD pigeonpea; the remainder is still under LD types, because eastern Uttar Pradesh is not agroclimatically suited to ESD types. Further valuable genetic variability has been generated under the AICPIP, and several varieties released for commercial production in the NWPZ: AL 15, ICPL 87, ICPL 151, Manak, Pant A 3, Paras, Pusa 84, Pusa 855, TT 5, TT 6, etc.

The objective of this workshop is to prioritize constraints to production and adoption of ESD pigeonpea. High yield, desired grain quality, and consistent performance over environments are the major breeding objectives considered for improved production.

Although considerable success has been achieved during the last 20 years in evolving ESD varieties of pigeonpea, their yields remain relatively low. In experiments in Australia, yields up to 8 t ha^{-1} have been realized, showing the very high yield potential of ESD pigeonpea under optimum conditions. Several constraints, however, restrict the performance of available improved varieties-climatic, edaphic, and biotic stresses-and these must be overcome before ESD pigeonpea can be widely adopted and its full yield potential realized.

Management Constraints

In India, results from experimental plots show that ESD pigeonpea can give yields of 2.5-3.0 t ha^{-1}; average yield reported from the NWPZ, where ESD varieties are widely grown, is 0.9 t ha^{-1}. This wide gap between potential and actual yields results mainly from management constraints; it could be substantially reduced by growing high-yielding varieties, using the recommended packages of improved practices.

Currently, farmers are not prepared to apply any inputs to the pigeonpea crop; because of its unstable performance, there is no surety of returns. Biotic and abiotic stresses often result in poor performance of pigeonpea. Hence the crop rarely receives any fertilizer or insecticide.

Climatic Constraints

The performance of the pigeonpea crop is strongly influenced by climatic factors, such as temperature, daylength, rainfall, and humidity. Temperature and daylength especially affect crop growth and duration.

Sensitivity to photoperiod and temperature

Pigeonpea is basically a short-day plant. Photoperiod x temperature interaction influences crop growth and restricts the scope of a variety to specified cropping situations. The spread of ESD pigeonpea varieties to changing environments required modification of their sensitivity to daylength and temperature. For example, late rainy-season and early spring sowing of ESD pigeonpea is possible with photoperiod-insensitive varieties, as flowering duration will be similar, regardless of date of sowing.

Fortunately, most of the ESD varieties appear to be relatively photoperiod-insensitive compared with the MD and LD types. Response to variation in photoperiod and temperature of popular ESD variety Prabhat was studied in Australia (Turnbull et al. 1981). The environmental factor that most influences time of flowering in ESD genotypes is temperature. This is evident from the wide variation in their duration at different locations. For example, photoperiod-insensitive variety Prabhat matured in 132 days when tested at Delhi but in only 100 days at Coimbatore. Efforts should therefore be made to develop genotypes relatively insensitive to a wide range of temperatures.

Rainfall and humidity

Rainfall and humidity are important climatic factors affecting the yield of pigeonpea. Erratic rainfall and cloudiness induce excessive flower drop and encourage insect pests. ESD varieties are highly sensitive to waterlogging at the seedling stage, and plant stand is often reduced by excessive rains and increased mortality from phytophthora blight. On the other hand, drought stress at podding stage reduces yields, and ESD pigeonpea types are more sensitive to intermittent drought at this stage than later types. However, ESD types have the advantage of being able to escape terminal drought stress, which longer-duration types cannot.

High humidity and cloudy weather at the time of flowering result in flower drop and nonsynchronous fruiting. For consistent performance, ESD pigeonpea should either be less sensitive to climatic factors or should be grown in a safer period to avoid the adverse effect of environment. If sowing date is to be changed, pigeonpea varieties should be more insensitive to temperature, so that sufficient dry matter is accumulated even in July sowings, which is not possible with temperature-sensitive varieties.

Edaphic factors

Rich, loamy soils that retain moisture well during the fruiting period are favorable for pod filling in pigeonpea. The effect of this factor was observed over the years by comparing the pigeonpea seed size at Karnal and New Delhi. Karnal soils, which are heavier and more water-retentive, produce 10-15% larger pigeonpea seeds than New Delhi soils.

On the other hand, continuously high soil moisture adversely affects the crop, resulting in nonsynchronous fruiting. Because pigeonpea is basically a perennial, excessive moisture induces nonsynchrony, as the plant reverts to the vegetative phase at the time of fruiting and there is competition between vegetative and reproductive sinks, resulting in excessive flower drop.

Biotic Constraints

Numerous insect pests and diseases affect the pigeonpea crop from seedling to maturity, the pod-borer complex being the most important in reducing yields of ESD genotypes.

Insect pests

The major insects affecting ESD pigeonpea are podfly *(Melanagromyza obtusa),* pod borer (*Helicoverpa armigera),* spotted pod borer *(Maruca testulalis),* and blister beetle *(Mylabris pustulata)*. Developing varieties resistant to these pests is a prime objective of our breeding programs. Four different approaches-nonpreference, antibiosis, tolerance, and avoidance-are used to develop resistant varieties. Field screening against insect damage has shown some indication of relative tolerance in a few genotypes. However, results are not consistent over environments, and no dependable sources of resistance have been identified for incorporation into desired agronomic bases. Confirmed results are not available to indicate any morphological trait that may cause the pod-borer complex to show nonpreference for a particular genotype. Similarly, little information is available on the nature of antibiosis. Interspecific crosses with *Cajanus (Atylosia)* species that offered some antibiosis/nonpreference have not been successfully exploited to develop pest-resistant varieties.

Use of the pest-avoidance approach, though complex, seems to be practically feasible for ESD pigeonpea. The incidence of pests can be considerably reduced by changing variety duration, altering sowing and harvesting dates, and suitably manipulating crop management to stagger the period of fruiting and pest buildup. Studies on the relationship of climatic factors and peak pest infestation period at IARI (Singh and Singh 1978) suggest that change in sowing time and varietal duration can help overcome the problem to a considerable extent.

Incidence of pod borer and podfly starts during the first half of October and reaches its peak during the second week of November. The incidence of pests starts declining when the temperature falls below 17°C. Low temperatures, wide variation in maximum and minimum humidity, and fewer hours of sunshine reduce the population buildup of insect pests. Short-duration varieties (150 days) are safer from pod borer than ESD varieties.

Incidence of blister beetle is more serious in ESD varieties than in the ACT-1 group. Extra-short-duration varieties start flowering in the second half of September, when the blister beetle population is also maximum. After the second week of October, this population is considerably reduced, and the later-flowering varieties of the ACT-1 group are relatively safe from blister beetle damage.

Development of varieties resistant to *H. armigera* appears to be a complex problem, considering the polyphagous nature of the insect. Some unconventional approaches, such as biological control using *Bacillus thuringiensis* (Bt.) and nuclear polyhedrosis virus (NPV), should be vigorously pursued to find a lasting solution to the problem.

The Division of Biotechnology at IARI is trying out Bt.; only preliminary results are available so far.

Diseases

Three major diseases, wilt, sterility mosaic disease (SMD), and phytophthora blight (PB), affect the pigeonpea crop at different growth stages. However, disease problems are more serious in LD types than in ESD types. In the northwestern zone, PB and SMD are relatively more important. Phytophthora blight occurs only in waterlogged conditions, and can be considerably reduced by providing proper drainage during the rainy season. The disease is more serious in the *Tarai* region of northern Uttar Pradesh and it often appears in epidemic form at Pantnagar. Sterility mosaic is also more serious in high-humidity areas. Wilt is of little consequence in ESD pigeonpea.

Several sources of resistance—mostly from MD and LD genotypes—have been recently identified and are being used in breeding programs. The prevalence of several races of the pathogens complicates the problem. The sources identified from early pigeonpea for resistance to wilt, PB, and SMD are ICPL 83027 and ICPL 84023.

Slow Early Growth

Pigeonpea has a very slow initial growth rate as compared with cereals and even other grain legumes. A major factor associated with this slow initial growth is a poor canopy cover as illustrated by a pattern of poor light interception (Lawn 1981). Light interception up to 30 days is < 10%, and even up to 60 days, hardly 50% of the intercepted light is utilized by the plant canopy. The markedly slower growth rate appears to be due to smaller seedling leaf area, since net assimilation rates of pigeonpea are comparable to those of other C_3 species (Rowden et al. 1981). The slow development of the canopy is desirable in the traditional late types, which are largely grown in mixed crops; however, it becomes an important limiting factor in ESD types, which have a short vegetative phase and are mostly grown as sole crops. Because of this slow early growth, ESD pigeonpea is highly susceptible to weed competition. The seedling crop is easily smothered by fast-growing weeds.

Fast early growth helps the plant produce optimum biomass in the short period available, which is an important factor determining yields of ESD pigeonpea. Hence efforts should be made to identify fast-growing genotypes. Genetic variability evaluated at New Delhi has shown some desirable trends, which need to be further evaluated.

Harvest Index

Harvest index is an important factor determining pigeonpea yields. Harvest index of pigeonpea is lower than that of cereals and even other grain legumes, such as soybean (Lawn and Troedson 1990). However, the harvest index of ESD genotypes is relatively high.

The role of harvest index, total dry matter, and pods per plant-an important yield-contributing character-in determining yield was studied in a set of 28 determinate and indeterminate genotypes of early-maturing pigeonpea at New Delhi (Table 2). In the determinate group, all the characters showed significant correlation with yield, except harvest index. Path coefficient analysis of these components indicated that both total dry matter and harvest index directly contributed to yield, while pods per plant had a negligible effect. Total dry matter, however, counteracts the effect of harvest index, indirectly reducing its total contribution. This suggests that total dry matter plays an important role, particularly in the determinate group, whereas increase in harvest index is often at the cost of total dry matter. Harvest index is higher in these varieties, even though their absolute grain yield is lower than that of the indeterminate group.

The relationships of these components were further considered for comparing the effects of harvest index and total dry matter on grain yield. It was observed that varieties with high yield did not have higher harvest index, but all the high-yielding varieties had relatively high total dry matter. The following conclusions can be derived from this study.

- Total dry matter and grain yield are relatively higher in the indeterminate than in the determinate group.
- Harvest index is relatively higher in the determinate group. Increased harvest index is not accompanied by increased total dry matter.
- High-yielding varieties have medium harvest index but invariably high total dry matter.

Table 2. Direct and indirect effects of pods per plant total dry matter (TDM), and harvest index (HI) on single plant yield of indeterminate and determinate genotypes of short-duration pigeonpea.

Character	Correlation with yield	Direct effect	Indirect effects through: Pods plant^{-1}	TDM	HI
			Indeterminate		
Pods plant^{-1}	0.407	-0.026		0.459	-0.026
TDM	0.833[1]	1.050			-0.206
			0.011		
HI	0.128	0.534		-0.405	
			0.001		
			Determinate		
Pods plant^{-1}	0.441	0.008		0.459	-0.010
TDM	0.838[1]	1.055			-0.206
			0.011		
HI	0.111	0.528		-0.009	
			0.009		

1. Excluding roots and fallen leaves.
Residual = 0.226.

Source: S.P. Singh (unpublished data).

- Very high harvest index in the determinate group is often at the cost of reduced total dry matter and not because of efficient partitioning.
- To achieve high yield, an optimum balance of harvest index and total dry matter should be arrived at by breaking undesirable linkages.

Prospects for Hybrid Pigeonpea

The development of commercial pigeonpea hybrids has become a viable proposition with the identification of a source of genetic male sterility at ICRISAT (Reddy et al. 1978). Besides this, an efficient pollen dispersal mechanism through insects has been reported by several workers (Onim 1981).

The natural male-sterile source first identified at ICRISAT is characterized by translucent anthers, and sterility is controlled by a single recessive gene ms_1 in a medium-duration background (MS3A and MS4A). Another source of genetic male sterility, reported by Wallis et al. (1981) in Australia, has shrivelled, nondehiscent anthers shaped like arrowheads. Male sterility is controlled by a separate recessive gene ms_2.

With the availability of these male-sterile sources, research work on hybrid pigeonpea gained momentum under the collaborative program between the Indian Council of Agricultural Research (ICAR) and ICRISAT, beginning in 1987. Under this program, 240 experimental hybrids of short duration were evaluated at various cooperating centers in different zones (Dubey and Asthana 1989). The results indicated the presence of 20-55% hybrid vigor for yield.

Subsequently, ICAR launched an intensive program of hybrid research in 1989, and more concerted efforts are being made at New Delhi, Hisar, and Ludhiana to develop ESD pigeonpea hybrids for cultivation in the northwestern zone of the country.

ICPH 8, developed at ICRISAT, was the first pigeonpea hybrid recommended for commercial cultivation in 1991 for the central zone. This hybrid yielded 30% more than the control variety, UPAS 120, and 15% more than Pusa 33 and ICPL 87. A large number of hybrids are being developed and tested under the coordinated program every year, with the objective of identifying heterotic combinations. During 1995/96, four hybrids-PHH 3, PHH 7, PHH 9, and PHH 98-are under advanced testing in the AVT-1 trials; 6 determinate and 52 indeterminate early hybrids are being evaluated separately in coordinated trials. PPH 4 was identified for release in Punjab. This hybrid yielded 32% more than the best control, UPAS-120, in the NWPZ. The results clearly showed that early-maturing pigeonpea hybrids can be successfully developed to fit into the pigeonpea-wheat rotation in the northwestern region of India.

The major activities under the Hybrid Pigeonpea Project are aimed at broadening the base of the available male-sterility system, searching for cytoplasmic male sterility (CMS), identifying heterotic crosses, and perfecting techniques for production of hybrid seed. Male sterility is being incorporated into several desirable backgrounds, including disease-resistant sources, such as ICPL 83024, ICPL 83027, and ICPL 84023.

Although a stable source of genetic male sterility is being commercially exploited, some practical difficulties have been encountered in commercial seed production using genetic male sterility. Roguing of 50% male-sterile sibs from the MS block and maintenance plots before pollination is a very tedious and labor-intensive job. For a lasting solution to this problem, a CMS source is essential. Work is being done on this at several research centers, and preliminary results from ICRISAT and the Bhabha Atomic Research Center, Bombay, suggest that it is possible to achieve the target in the near future.

Interspecific crosses between *C. sericea* and *C. scarabaeoides* have given sterile single plants in the advanced progenies and the mechanism of sterility and restoration is being worked out. The possibility of induced mutagenesis as a source of CMS is being explored at several centers, including IARI.

Techniques are being perfected to reduce the cost of hybrid seed by reducing the cost of production. The estimated cost of hybrid seed production varies widely among different centers (Verma and Sidhu 1995). However, by a broad estimate, considering all factors influencing hybrid seed production, a reasonable cost would be around Rs 50 a kg. This cost can be further reduced by taking a ratoon crop for multiple harvests in the same year.

Ideal Plant Type

The ideal plant type for ESD pigeonpea should have

- Extra-short duration (110-120 days) and determinate maturity.
- Relative insensitivity to temperature.
- Relative insensitivity to climatic changes, such as rainfall, humidity, and cloudy weather.
- Short stature and compact, determinate growth habit.
- Vigorous early growth, with greater leaf area at the seedling stage.
- Plant canopy designed for maximum light interception.
- Improved flower and pod retention to increase the yield potential.
- High biomass accompanied by high harvest index.
- Responsiveness to improved management.
- Tolerance of the major biotic stresses.

These components of plant type are suggested for future improvement.

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Production of Extra-short-duration Pigeonpea Seed

K C Jain and Y S Chauhan[1]

Introduction

Pigeonpea is a partially outcrossing crop. Natural outcrossing observed at ICRISAT Center, Patancheru, was 20.4% and a mean of 22.6% at ICRISAT Center, Badnapur, Coimbatore, and Varanasi locations (Bhatia et al. 1981). This high percentage of outcrossing poses serious problems in maintaining the purity of released cultivars. Plant breeders have followed different methods to prevent natural outcrossing and produce quality seed; however, no such attempts have been made at farmer's level to help retain the purity of cultivars they grow.

Farmers' acceptance of a particular variety will depend on adequate returns, stable performance, and compatibility in cropping systems. The production and use of quality seed are essential ingredients for increasing yields of a crop and also the farmer's net income.

In this paper, we summarize the current status of seed production of extra-short-duration (ESD) pigeonpea varieties, problems encountered, and future needs for the production of quality seed.

Current Status

Traditionally, medium- and long-duration pigeonpea varieties have been grown throughout India. However, in the past two decades, short-duration (SD) pigeonpea cultivars-UPAS 120, Manak, and others-have been developed and are cultivated in Haryana, Punjab, and western Uttar Pradesh in northern India, where wheat is the most important winter crop. An ESD pigeonpea variety, Prabhat, was released in 1976 for the pigeonpea-wheat rotation, but probably because of its small seed mass (6.7 g/100 seeds), not widely adopted. At the Directorate of Pulses Research, Kanpur, Uttar Pradesh, there has been no indent for the production of breeder's seed of

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this variety since 1990. Other ESD varieties have since been released, and more are expected; if these are to be widely adopted, it is essential to develop a strategy for producing quality seed and making it easily available to farmers. However, there are many constraints to seed production, some applicable to pigeonpea in general; some specific to ESD varieties.

Constraints

- Lack of varieties. Release of ESD varieties that can compete in contemporary agriculture is urgently needed. Those already developed, for instance, AL 15 and AL 201, have not been well adopted in farmers' fields. Seed growers are not producing seed of Prabhat.

- Low priority for pigeonpea seed production. Seed production in both public and private sectors is dominated by hybrids of cereals and other high-value crops. The demand for seed of pulses, including pigeonpea, is inconsistent and low, because farmers keep their own seed for sowing. Therefore, at present it does not appear lucrative to produce pigeonpea seed.

- Poor linkages among researchers, seed producers, and farmers. In the past, research activities on pigeonpea variety development and seed production were not linked to the extension programs. Such a link is vital to the development and effective transfer of appropriate technology to farmers. It serves both to acquaint farmers with the features of newly developed varieties and to give researchers and seed producers feedback on farmers' problems and constraints to the adoption of a particular variety in a given region.

- Improper seed storage. Farmers generally save their own pigeonpea seed for the next crop. For ESD pigeonpea, this means storing seed for 8-9 months, from harvest to next sowing, and most farmers do not have the facilities for storing it under the right conditions. Stored grain pests cause considerable damage to pigeonpea seed. All these conditions lead to the deterioration of seed quality.

- Poor seed quality. In pigeonpea, the rate of seed replacement is very low. Often farmers use their own seed for the next year's sowing or exchange with other farmers. Such seed may be damaged by pod borers or bruchids or improperly stored. It has also been observed that if rainfall occurs at maturity, seed sometimes germinates in the pod, and may also be infected with grain mold. All these factors reduce viability and render seed unfit for cultivation. Infected seed is also unsafe for human food or animal feed. The use of inferior seed results in poor germination, low plant stand, and low yield.

Future Needs

Production of quality seed

To exploit the genetic yield potential of a variety fully, production and distribution of quality seed is essential. Since breeder's seed is the starting point for the production of foundation and certified seed, the utmost care is needed to maintain the purity of breeder's seed.

The seed crop should be grown in a well-drained field. It should be well fertilized, irrigated if needed, and protected from insect pest damage. Seed should be treated with fungicides before packing and stored in a cool, dry place.

Gupta et al. (1991) have suggested the following procedure to maintain and produce pure breeder's seed of pigeonpea.

Step 1. From the original pure elite strain under maintenance and multiplication, harvest the selfed seed from about 500 individual plants that are true to type in appearance and seed characteristics. To overcome the problem of genetic drift, the number of individual plants selected should be as large as possible, not less than 250. These can be termed nucleus plants or progenies.

Step 2. In isolation, separated by at least 200 m from other pigeonpea plots, grow single plant progenies (SPP) from the selfed seed harvested from 500 individual plants.

Step 3. Observe the visual characteristics of the genotype and discard rows with even a single off-type plant before flowering.

Step 4. In the remaining true-to-type SPP rows, self two or more individual plants (totaling 500 or more plants). The selfed seed from these plants is used for growing SPPs (nucleus progenies) the following year, to continue the cycle.

Step 5. Bulk the remaining open-pollinated seed from the field. This seed can be used as breeder's seed or as source seed for the production of breeder's seed in an isolated field, with rigorous roguing of the off-type plants before anthesis.

Specific responsibility for seed production

Currently, the area of adoption of ESD pigeonpea is limited, and the demand for seed is not large enough to attract the private seed sector. However, the prospects for adoption of newly developed ESD genotypes for growing in rotation with wheat in northern India appear bright, and ESD pigeonpea can become a very important crop in the region. We therefore suggest that the specific responsibility of seed production be given to public sector seed companies.

For some time, until the demand for seed increases and the seed production of ESD pigeonpea becomes commercially viable, some sort of subsidy may be helpful to compensate for losses on unsold seed stocks.

Delayed/off-season seed production

Seed production should be done in the most favorable climatic conditions to obtain full expression of cultivar characters and high yield. Relatively dry and cool locations are best, as excessive rainfall favors incidence of grain mold and makes harvesting extremely difficult; seed also germinates in the pod, and pods shatter. Therefore, sowing should be delayed enough to let the seed crop mature in dry weather.

Seed production can also be undertaken in the off-season where climatic conditions are favorable.

Seed storage

Seed storage of ESD pigeonpea varieties requires special consideration. Many factors influence the viability of seed during storage: seed moisture, relative humidity, temperature, and infestation by stored grain pests can greatly reduce the quality of seed. The bruchid *Callosobruchus maculatus* is the most common pest of stored pigeonpea seed (Singh and Jambunathan 1990). Although optimum conditions can be maintained in environmentally controlled storage rooms, such a controlled environment cannot be created at the farm level, and the seed is generally stored under suboptimal conditions. Simple storage methods developed by agricultural universities and other research institutions need to be popularized through meetings, field days, video shows, pamphlets, radio, television, and newspapers.

Incorporation of partial cleistogamy character

The natural outcrossing in pigeonpea poses serious problems in the maintenance of cultivar purity. A derivative from pigeonpea cultivar T 21 and *Atylosia lineata (=Cajanus lineata),* in which flower opening is considerably delayed, was identified at ICRISAT (ICRISAT 1980). This delayed opening considerably reduces the natural outcrossing, which was a mean of 2.5% and a maximum of 8% in the derivative, as against the 36-40% reported earlier at ICRISAT Center (Saxena et al. 1993). Once this character is incorporated into the well-adapted and high-yielding cultivars and promising genotypes, it will be possible to retain the genetic purity of cultivars for a longer period.

Selection for grain-mold resistance

When rainfall occurs at maturity, pigeonpea seed can be infected by grain mold and become unfit for sowing; it is also unfit for human or animal consumption. We suggest that germplasm accessions, breeding lines, and segregating populations be screened for grain-mold resistance. This can be done under natural conditions where rainfall occurs at maturity. Screening can also be done under artificial conditions, using perforated irrigation pipes or sprinklers to produce the required humidity.

Maintenance of seed purity at farmer's level

Considerable spread of released pigeonpea varieties takes place through seed exchange among farmers. If proper precautions are not taken, the seed may get contaminated with other varieties due to outcrossing or mechanical mixing. Maintenance of seed purity is especially important for determinate cultivars, which, if contaminated with seed of indeterminate ones, may mature unevenly and delay wheat sowing. To maintain seed purity at the farm level, farmers could be educated to follow simple procedures through leaflets, videos, and at Krishi Vigyan Kendras.

Some of the steps that will help minimize seed contamination are as follows:

1. All off-colored seed should be removed before sowing.
2. Seed production plots of ESD varieties should be at least 100 m away from plots of other varieties.
3. Just before flowering, all the off-type plants should be rogued. The off-type plants can be identified from the appearance of the plant if it differs from the majority of the plants. The indeterminate off-type plants stick out of the canopy of the determinate variety and are therefore easily identifiable. Farmers should be convinced that the early removal of such plants will ensure synchronous maturity and will not necessarily reduce yield significantly.
4. To prevent mechnical mixing of seed, care should be taken at the time of harvest to separate from the harvested bulk any off-type plants that might have been missed during roguing.

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Transfer of Improved Pigeonpea Production Technologies through Demonstrations

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Introduction

The majority of the population in India dwells in rural villages, and agriculture forms the main base for socioeconomic development in the country. Agricultural progress in any country depends upon the spread to farmers of reliable, practical, and accurate information related to recommended improved practices. Studies have quite clearly shown that communication is much more effective when it starts with problems that farmers consider important than when it starts with solutions that researchers consider useful for farmers (Windhal and Signitizer 1991). This fact is now well recognized by top-level administrators in the agricultural extension services (Macklin 1992).

The Indian Council of Agricultural Research (ICAR), the state agricultural universities, and the state departments of agriculture have their own extension programs for farmers. The 'lab-to-land' programs of ICAR can reach only a small proportion of farmers; for instance, only about 2 out of every 100 000 farm families participated in them during the Seventh Five Year Plan period, 1985-90 (ICAR 1988). Therefore, it is uncertain whether such programs are really increasing the competence of the farmers in a meaningful way or merely increasing the competence of researchers by bringing them in direct contact with some farmers, useful though this may be.

The slow movement of technology to farmers in India is often criticized, considering that the Government of India employs over 300 000 personnel to work in agricultural research, development, and extension (RD&E). However, the remarkable increases in agricultural production over the last 30 years suggest that linkages between technology generation in agricultural research and on-farm practices have indeed improved over this period. There are numerous examples in both irrigated and rainfed agriculture of widespread on-farm adoption of improved varieties and management technologies. Nevertheless, we feel that there is much further scope for

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close contact between RD&E personnel and farmers, not only to move viable technologies towards adoption at a faster rate but also to facilitate feedback of researchable issues to the scientists.

Although pigeonpea is an important pulse crop in Haryana, pulse crops in general and pigeonpea in particular have not received adequate attention from researchers and producers. Now, with the changing cropping pattern, pigeonpea is gaining increasing popularity in Haryana. The prevalent cereal-cereal cropping system exhausts the soil and requires considerable investment in fertilizer. Thus there is a need to introduce legume-cereal rotations so that at least one component of the cropping system needs only light fertilizing, if any, and indeed may even improve soil fertility. Fortunately, there has been a remarkable increase in area and production of pigeonpea in Haryana (Table 1).

Table 1. Area, production, and mean yield of pigeonpea in Haryana, India, 1985-91.

Year	Area ('000 ha)	Production (' 000 t)	Mean yield (t ha^{-1})
1985/86	24.1	25.7	1.1
1987/88	39.3	32.2	0.8
1988/89	44.2	48.2	1.1
1990/91	52.3	49.6	0.9

Source: Haryana Statistical Abstracts.

Constraints to Pigeonpea Productivity

The relatively low and stagnant yield levels of pigeonpea in Haryana can be attributed to several reasons.

- Limited yield potential of the commonly grown indeterminate cultivars and farmers' unawareness of improved varieties, especially extra-short-duration (ESD) types that would better permit timely sowing of wheat as a subsequent crop.
- Nonavailability of certified seed.
- Serious infestations of weeds, such as *Trianthema monogyna* and *Cynodon dactylon.*
- Diseases, especially fusarium wilt, sterility mosaic disease (SMD), and phytophthora blight.
- Devastating insect pestsi especially the leaf webber and the pod borer.
- Drought and poor seedling establishment.
- Waterlogging in the early vegetative phase.
- Poor management practices, e.g., lack of manure, insufficient weeding, and inappropriate use of *Rhizobium* cultures, fertilizers, and herbicides.
- Low priority for pigeonpea as a crop; rainfed cropping on marginal land.

- Socioeconomic factors, such as lack of resources and inability of farmers to bear much risk; low farm-gate prices offered by middlemen for pigeonpea; limited consumption of pigeonpea *dhal* in Haryana; limited exposure of farmers to improved practices, because of low literacy among farmers and inadequate extension input from state agriculture agencies.

Thus, for pigeonpea in Haryana, percolation of production technology is limited. Much scientific technology is available, but only a small proportion of it is being taken to the farmer.

Researchable issues

In view of the constraints described, we suggest that the following researchable issues should take priority:

- Breeding and selection of high-yielding ESD pigeonpea genotypes with enhanced resistance to the major pests and diseases.
- Improved methods of chemical control of insect pests.
- Farm-level techniques to produce and store seed, and state and national programs to protect quality of seed.
- Intercropping studies in pigeonpea, accompanied by efficient weed control practices for different climatic zones.
- Change in crop rotation practices to break the continuous rice-wheat cycle. In Haryana, the large area under rice includes areas not really suited for the crop, as it causes an alarming depletion of groundwater. Pigeonpea can be an alternative crop in such systems, but this is only possible if ESD genotypes are used, to ensure timely sowing of wheat.
- Farmers' participatory research for challenging problems and technology development in pigeonpea production.
- Transfer of promising technology from research stations to cultivators' fields through demonstrations, adaptation trials, and operational-scale research; socioeconomic evaluation of its appropriateness and acceptance by farmers.

Strategies for Demonstrations

The main objective of demonstrations is to show, under real farm conditions, the production potential and profitability of the latest improved technologies. This includes evaluating new cropping systems involving pigeonpea varieties recommended for different agroecological and cropping situations as compared with prevailing farmers' practices. In developing policies for on-farm demonstrations, the following points should be considered.

Whole-package demonstrations

These demonstrations may help to evaluate the productivity, potential, and profitability of an entire package of improved practices over the prevailing farmers' practices in different agroecological zones. The evaluation must be done mainly in terms of proportionate increase in yield attributed to the improved technology over prevailing farmers' practices and the incremental benefit:cost ratio (IBCR). Contrary to widespread misconception, the whole package of improved technology usually does not involve a sizeable investment. To accurately measure the extent of yield advantage over local practices, critical low-cost inputs for pigeonpea production should be used at all demonstration locations: appropriate choice of varieties, timely sowing, use of recommended seeding rate, sowing of quality seed treated with *Rhizobium* culture and chemical protectants, scientific crop rotation in conjunction with the recommended fertilizer dose, need-based plant protection measures, and irrigation management.

Cropping system demonstrations

Researchers need to identify profitable and viable cropping systems involving pigeonpea as mixed, sequential, and intercrops. The most promising cropping systems have been tested to a limited extent under real farm situations in various pigeonpea-growing states. These systems include intercropping of pigeonpea with maize, sorghum, or mung bean; rotation of ESD pigeonpea with wheat, late potato, sugarcane, and sunflower. These cropping systems need to be evaluated for profitability and sustainability in Haryana.

Component technology demonstrations

Demonstrating the efficacy of a single component or selected components of the whole package is yet another method of highlighting the benefits of improved technologies. Examples include newly developed ESD pigeonpea genotypes and recommended technology with respect to fertilizer and pest, water, and weed management. These need to be evaluated separately against the existing cultivation practices, considering the most critical factors in an area.

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Constraints to and Prospects for Adoption of Extra-short-duration Pigeonpea in Northern India: Some Socioeconomic Aspects

P K Joshi and S Pande[1]

Introduction

Nonavailability of extra-short-duration (ESD) varieties was considered an important constraint to the adoption of pigeonpea in the rice-wheat cropping systems of northern India. Concerted research efforts have succeeded in developing ESD pigeonpea varieties, but, despite their availability now, some questions still remain:

- Will farmers of the region adopt ESD pigeonpea in preference to other crops in the existing cropping system?
- Now that the constraint of duration has been overcome, are there other constraints that will hamper the adoption of pigeonpea?

This paper identifies possible socioeconomic constraints to the adoption of ESD pigeonpea in northern India, explores the prospects for its becoming an important pulse crop in the region, and proposes the direction that future research and policy should take.

Extra-short-duration pigeonpea is a new introduction into the existing rice-wheat system, and farmers are yet to experience its performance and adaptability. Therefore, the constraints and prospects discussed in this paper are on the basis of the farmers' past experience in cultivating pigeonpea. Some of our observations are also based on the Rapid Rural Appraisal (RRA) survey conducted in September 1995 to assess the prospects for legumes in northwestern India. The survey covered the districts of Ambala, Karnal, Kurukshetra, Panipat, and Sonepat in Haryana; Fatehpur Sahib, Ferozepur, Jalandhar, Ludhiana, and Ropar in Punjab; and Bijnor, Dehradun, Moradabad, Nainital *(Tarai),* Rampur, and Saharanpur in Uttar Pradesh.

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Constraints to Cultivation of Extra-short-duration Pigeonpea in Northern India

Yield and profitability

Crop yield and profitability are the most important determinants of cropping patterns and crops grown in an area. Historically, pigeonpea has had a low status in the cropping system. Unlike cereals, pigeonpea and other pulses are considered subsidiary crops (Sharma and Jodha 1982). Thus pigeonpea was often relegated to marginal soils, as irrigated and fertile lands got diverted to wheat and rice, where technology-based increases in both yields and prices made these crops more profitable (Acharya 1993).

Our survey showed that the average yield of existing pigeonpea cultivars ranges from 0.6 t ha^{-1} in Mohendergarh district to 1.4 t ha^{-1} in Ambala district of Haryana; is < 1 t ha^{-1} in all districts of Punjab; and is 1 t ha^{-1} in all districts of western Uttar Pradesh except Badaun, Bijnor, Meerut, Moradabad, and Rampur. These low yield levels keep pigeonpea from competing with other crops-for instance, rice-for a place in the cropping system, as its profitability is negligible. Therefore, the pigeonpea area remains small and restricted to marginal environments.

The yields of ESD pigeonpea varieties in the Arhar Coordinated Trials (ACT) in Sardar Krushinagar were <1.5 t ha^{-1} during 1993/94 and 1994/95. Yields reported from trials in Pantnagar and Ludhiana in earlier years never exceeded 2.0 t ha^{-1}: the best yields at Ludhiana were of ICPL 83015 (1.4 t ha^{-1}) and AL 13 (1.2 t ha^{-1}) in 1989/90; and of Pusa 85 (1.2 t ha^{-1}), ICPL 88001 (1.13 t ha^{-1}), and ICPL 83015 (1.12 t ha^{-1}) in 1990/91. Similarly, at Pantnagar, best yields were observed for Pant A1-1 (1.7 t ha^{-1}) and T 21 (1.6 t ha^{-1}) during 1989/90.

These yield levels were achieved under the best management conditions; therefore, the probability of achieving even these experiment station yields in farmers' fields is very low. Our survey in northwestern India showed that a minimum yield of 2.5 t ha^{-1} is required if pigeonpea is to compete with other crops for acreage allocation in the cropping system.

Price spread and consumers' preferences

The retail prices of pigeonpea throughout the country are rising steeply, and it is important to know whether farmers are getting a share of this rise, or whether the middlemen and traders are swallowing most of the gains. We found that the farmer's share of the consumer's rupee for pigeonpea is much lower than that for cereals such as rice, wheat, and maize.

On an average, the price spread (the difference between the price received by the farmer and the price paid by the consumer) for pigeonpea *dhal* is about Rs 15 kg^{-1}, while for rice it is only Rs 0.84 kg^{-1}. Although pigeonpea and paddy go through similar processes of dehulling/dehusking to make dhal/rice, the farmer gets a significantly lower share of the consumer's rupee for pigeonpea (40%) than for rice (85%). Therefore, the steep increase in retail prices of dhal may not indicate that there will be a corresponding increase in adoption of pigeonpea into the rice-wheat system.

Since pigeonpea dhal is not popular in Haryana, Punjab, and western Uttar Pradesh, the bulk of the produce in this area is marketable surplus; therefore, the farmers look at the prices they will receive for their produce to determine whether to grow the crop. In eastern and central Uttar Pradesh and Bihar, however, the majority of the farmers do consume pigeonpea dhal; therefore, their decisions about growing pigeonpea are influenced both by the price they expect to receive as producers and by that they expect to pay as consumers.

Market access and government support

Market access-especially the output market-and government support are other important incentives to acreage allocation of any crop. Experience has shown that government support to pulses is not as effective as that for cereals and oilseeds. The Government of India regularly announces the minimum support prices for pigeonpea along with other crops (Table 1). Ironically, farmers do not get a competitive pigeonpea market for their produce. Cereals and oilseeds have better developed and competitive markets. Malik (1994) reported that the shifts in the relative profitability of rice-wheat have come about not only because of the technological breakthroughs achieved in the cultivation of these two crops, but also because of government intervention in input and output prices and market support. This has not happened with pigeonpea and other pulses.

Our observations about market access confirm the findings of Kelley et al. (1990), who reported that in the Telangana region of Andhra Pradesh, marketing rice posed none of the problems that marketing short-duration (SD) pigeonpea in October or November did. Kelley et al. (1990) further reported that rice, castor, and cotton have relatively better developed markets in the region than pigeonpea; thus there is more price risk associated with SD pigeonpea. Similarly, in northern India rice, wheat, and sugarcane are the most widely grown crops; therefore, the market network for these crops is better developed than that for pigeonpea.

Table 1. Minimum support prices (Rs t^{-1}) of different crops announced by the Government of India, 1990-94.

Year	Pigeonpea	Paddy	Safflower	Sunflower
1990	4800	2050	5700	6000
1991	5450	2300	6400	6700
1992	6400	2700	7200	8000
1993	7000	3100	7600	8500
1994	7600	3400	7800	9000

Source: Government of India (1995).

Extra-short-duration pigeonpea in the rice-wheat system may face two major marketing problems: (1) only a low volume of produce is available with its producers; (2) very few private traders deal with pigeonpea, so that there is little competition for better prices.

Labor and mechanization

With the introduction of high-yielding rice and wheat varieties and the growing number of sugar mills in northern India, a kind of specialized farming has emerged, especially in northwestern India. A large area is occupied by rice in the rainy season and by wheat in the postrainy season. In some parts, sugarcane is grown as an annual crop. The available labor also specializes in different operations of rice, wheat, and sugarcane cropping. Farmers have procured specific tools required to cultivate these crops. Switching over to growing ESD pigeonpea in these areas would mean underutilization of fixed factors and additional capital requirement to procure whatever new items are needed for its cultivation. Although this may not be a major constraint to the adoption of ESD pigeonpea, it is an important consideration when the competing crops are either more or equally remunerative.

Another problem encountered in growing ESD pigeonpea is the nonsynchronous flowering and maturity of the indeterminate types, which (1) delays sowing of the following crop, (2) prevents mechanical harvesting, and (3) adds to the production costs the high cost of hand harvesting.

Risk and stability

Pulses in general, including pigeonpea, are more susceptible to insects, diseases, and other stresses than the improved varieties of cereals that have been bred for more tolerance of these stresses. The probability of crop failure in pigeonpea is much higher than in rice or sugarcane. In our 1995 RRA survey in northwestern India, farmers' perception of pulses in general, and pigeonpea in particular, was that they may incur losses in cultivating these crops despite following intensive plant protection measures.

In a collaborative project of the All India Coordinated Pulses Improvement Project (AICPIP) and ICRISAT on 'Effect of Pigeonpea Genotypes on Productivity of Pigeonpea-Wheat Rotation,' 2 years' yields of ESD and SD pigeonpea varieties at Sardar Krushinagar were compared. It was observed that-except for AL 15, ICPL 88001, and Pusa 85-yields of all varieties were highly unstable: yield differences between 1993/94 and 1994/95 were more than 0.5 t ha^{-1}.

At Pantnagar (Uttar Pradesh), in the same trial, the seedling pigeonpea crop suffered a devastating phytophthora stem blight attack; consequently, the trial was abandoned (Ali 1994). The farmer cannot afford such an eventuality when better options are already available.

Multipurpose crops

Farmers have multiple objectives in selecting a crop; in choosing to grow pigeonpea, they look not only for high grain yield but for fuelwood as well. It was estimated that pigeonpea sticks accounted for about 14% of domestic fuel energy used in Haryana (Joshi and Agnihotri 1983). In the northwestern region of India, it was observed that the large farmers are now growing pigeonpea to meet the dhal requirements of the migrant laborers from eastern Uttar Pradesh and Bihar and also as an important source of fuel for them.

Extra-short-duration pigeonpea plants are short in stature and offer very little fuelwood. In areas where multiple objectives are an important criterion for decision-making, ESD pigeonpea will have some tough competition from medium- and long-duration pigeonpea.

Salt-affected and waterlogged soils

Pigeonpea is highly susceptible to salt-affected (both sodic and saline) and water-logged soils. These are two important soil-related constraints to adoption of ESD pigeonpea. Most of the districts in northern India are seriously affected by sodicity/salinity and waterlogging. Though large areas of sodic soils in Punjab and Haryana have already been reclaimed (Joshi and Datta 1990), only rice performs reasonably well on them. Pigeonpea still gives low yields if grown on these soils. Mishra and Singh (1995) reported yield reductions of 70-90% in pigeonpea grown on moderately sodic soil (pH 8.0-9.0). Similarly, waterlogging, either in good quality or saline groundwater, adversely affects pigeonpea performance. Singh (1992) reported that in Hisar district of Haryana, waterlogging caused complete failure of the pigeon-pea crop, reducing net income from it by almost 100%, whereas net income from rice was reduced by only 10%. Kelley et al. (1990) reported that in prolonged wet conditions, growth of SD pigeonpea was extremely poor and plants succumbed to root rot in the assured-rainfall area of village Kanjara in Akola district, Maharashtra.

Prospects for Extra-short-duration Pigeonpea

Adoption of ESD pigeonpea in the rice-wheat cropping systems is expected to enhance income and improve the sustainability of the existing cropping system by (1) replacing lower-value cropping systems; (2) minimizing risk in production; (3) saving inputs, especially water and fertilizer; and (4) serving as a catch crop. The related issues, prospects, and target regions for ESD pigeonpea will be different in each case. These are summarized here.

Replacing lower-value cropping systems

Besides the rice-wheat cropping system, several lower-value cropping systems are followed in northwestern India, maize-wheat and millet-wheat being the most important. Crop duration may have been a constraint to adoption and production of pigeonpea earlier; now, however, ESD pigeonpea cultivars may replace maize and millet if pigeonpea becomes more profitable than these crops.

The possibility of replacing maize is in districts Hoshiarpur and Ludhiana in Punjab; Bulandshahr and Farrukhabad in Uttar Pradesh. Replacing millet with ESD pigeonpea may be possible in Gurgaon, Hisar, Jind, Mohendergarh, Rohtak, and Sonepat in Haryana; Aligarh, Agra, Badaun, Etah, and Mathura in Uttar Pradesh.

The availability of ESD pigeonpea cultivars combined with inflationary pressures may induce farmers to grow pigeonpea in rotation with wheat in place of maize or millet. However, such crop substitution due to higher market prices should not be considered the contribution of research and improved technology. The rising price trend is not a welcome phenomenon, as it is not in the larger interests of society. It adversely affects the consumer without much gain to the producer. Higher prices should not be viewed as a permanent solution for introducing ESD pigeonpea into existing cropping systems. If farm harvest prices of pigeonpea start oscillating in the region, pigeonpea acreage will decline further in subsequent years to avoid the price uncertainty. We therefore suggest that efforts be directed to enhancing the yield potential of ESD pigeonpea through genetic manipulation and improved agronomic practices.

Minimizing risk

Extra-short-duration pigeonpea may be introduced to minimize the risk and instability in production during the kharif season. There are districts where pigeonpea yields are more stable than those of rice, maize, or cotton; these districts could be targeted for introducing ESD pigeonpea if the objective is to minimize risk.

The coefficient of variation of pigeonpea yields was lower than that of rice yields in Gurgaon and Jind districts of Haryana and Bulandshahr, Farrukhabad, and Mathura districts of Uttar Pradesh. Pigeonpea yields were more stable than maize yields in Ferozepur, Bhatinda, and Patiala districts of Punjab; Gurgaon, Jind, and Rohtak districts of Haryana; and Aligarh, Bareilly, Etah, Farrukhabad, and Mathura districts of Uttar Pradesh. Compared with cotton yields, pigeonpea yields were found to be more stable in all districts, except Ropar in Punjab and Ambala, Hisar, Karnal, and Mohendergarh in Haryana. Pigeonpea yields were more stable than rice yields in several important districts: Banda, Bahraich, Ballia, Ghazipur, Gonda, and Jhansi.

Saving water and soil nutrients

Existing irrigation price policy, both canal and groundwater, is highly subsidized and biased in favor of crops with high water requirements, such as rice and sugarcane. This policy has resulted in a rapid decline of groundwater in several intensively cultivated regions (Table 2). This decline is in turn leading to low discharge of

Table 2. Changes in groundwater table in selected villages of Haryana and Punjab, India/1983-93.

State	District	Village	Depth of groundwater• table (m)		
			1983	1988	1993
Haryana	Karnal	Nangala Megha	30-40	40-50	50-60
		Shakhpura	20-30	30-40	40-50
		Shangarh	50-55	45-50	70-75
	Kurukshetra	Mathana	45-50	60-70	70-80
		Sarsma	40-50	55-60	70-72
		Sindholi	28-30	38-40	48-50
Punjab	Fatehgarh Sahib	Polomajra	35-37	42-45	50-52
	Jalandhar	Cohgarh	15-16	20-22	26-30
		Masumpur	20-22	25-28	35-38
		Pratappura	35-38	40-42	50-55
		Teheng	25-28	30-32	35-38
	Ludhiana	Chella	35-38	40-42	50-52
		Nagla Hiran	30-32	40-42	45-48
		Samrala	35-40	45-50	55-60
	Patiala	Gaggar Sarai	25-30	28-30	45-50
		Pankherpur	40-42	44-46	48-50

Source: Singh and Singh (1993).

groundwater, which often makes it difficult to provide enough water for rice and other crops with similar high water requirements. In such situations, farmers are looking for some alternative crop, such as pigeonpea, which can fit into the rotation with winter crops. Extra-short-duration pigeonpea requires less water than rice and can best fit into the existing crop rotation with wheat; thus it will be an important alternative to rice where water is scarce and where frequent electricity cuts preclude pumping up groundwater.

In our recent survey, we observed that SD pigeonpea is emerging as an important pulse crop in the districts of Karnal, Kurukshetra, and Sonepat in Haryana and Fatehpur Sahib, Jalandhar, and Ropar in Punjab, where the water table is falling rapidly. There is relatively greater scope for ESD pigeonpea in these areas, as scarcity of groundwater is compelling farmers to change cropping patterns.

Farmers in Haryana, Punjab, and western Uttar Pradesh also reported that the cost of rice cultivation is increasing rapidly. To maintain yield levels, farmers have to use three to four times more fertilizer in rice and wheat than they were using in the late 1970s. Extra-short-duration pigeonpea requires fewer inputs and less cash outlay than rice and other cereal crops, and also improves soil fertility. The Government's recent decision to withdraw fertilizer subsidy may further increase the cost of rice and wheat production. Pigeonpea offers the advantage of fixing nitrogen, which can be used by the subsequent crop. Johansen et al. (1990) have shown that ICPL 151 benefited a succeeding wheat crop to the extent of 40 kg ha^{-1} N when compared with a millet or fallow control.

Extra-short-duration pigeonpea as catch crop

Extra-short-duration pigeonpea has tremendous potential as a catch crop in a 2-year rotation with sugarcane. Farmers in the sugarcane-growing regions generally keep the land fallow after the harvest of sugarcane until the planting of the next crop. This period can best be utilized by taking one crop of ESD pigeonpea in a cycle of 2 years. The districts in northwestern India with potential for this rotation are Jalandhar and Ropar in Punjab; Ambala and Rohtak in Haryana; and Bareilly, Bijnor, Bulandshahr, Meerut, Moradabad, Muzaffarnagar, Rampur, Saharanpur, and Shajanpur in Uttar Pradesh.

Future Strategy

Yield Enhancement

The most urgent initiative needed is to enhance the yield levels of ESD pigeonpea to competitive levels. In the northwestern region of India, farmers reported that a variety yielding about 2.5 t ha^{-1} may compete with alternative irrigated crops. Johl (1984) observed that pigeonpea yields should be increased by 169% in Punjab if pigeonpea is to compete with rice. It is therefore necessary to improve the yield potential of ESD pigeonpea either through genetic manipulation or resource management research.

On-farm trials and demonstrations

Farmers are completely unaware of the ESD pigeonpea varieties. To disseminate information about them, large-scale demonstrations should be conducted. Farmers in the northwestern part of India reported that an effective extension network existed when high-yielding varieties of rice and wheat were introduced. The extension staff regularly visited the farmers and kept them informed about the latest technology of rice and wheat production. In pulse production, however, extension is almost negligible. Therefore, there is a need to concentrate effort on demonstrating the benefits of ESD pigeonpea in the rice-wheat system.

Seed availability

Nonavailability of good quality seed is a major constraint to the adoption of improved varieties of pigeonpea. Most of the public and private seed companies in northern

India are concentrating on improved varieties of rice, wheat, and some oilseeds. Not much emphasis has been given to pulses in general. It is therefore necessary that the seed companies be involved in popularizing the ESD pigeonpea, and be provided with seed materials for multiplication and marketing.

Market access and government support

As stated earlier, pulses in general do not have as good a market as do cereals, for two reasons: (1) low volume of produce compared with cereals; (2) lack of a good consumer market in the region, which discourages traders from procuring pigeonpea, because of high transportation costs. A well-organized market should be developed through cooperative, corporate, or government support for pulses in general and pigeonpea in particular.

Conclusion

There are still constraints to the adoption and cultivation of ESD pigeonpea in northern India. The major constraint is the absence of a significant technological breakthrough in enhancing yield potential. This is followed by the high risk and uncertainties involved in the production of pigeonpea. The other constraints are related to market access, salt-affected and waterlogged soils, plant traits, etc. However, with the changing scenario, the crop has better prospects in regions where the water table is declining and adversely affecting the soil fertility. Extra-short-duration pigeonpea may also be accepted in areas where it can give more stable yields than those of rice, maize, and cotton. The need is to further increase yield potential of ESD pigeonpea and develop a good seed supply and output market for fast adoption to improve the sustainability of the rice-wheat system.

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Summary of Discussions

Four groups, broadly representing breeders, agronomists, extensionists, and socio-economists, met to deliberate on the assigned areas:

I. Improving plant type in extra-short-duration (ESD) pigeonpea
II. Improving management of ESD pigeonpea
III. Extension and demonstration
IV. Cropping systems, seed production, and socioeconomic aspects.

Each group discussed the following common issues, outlined by C. Johansen.

- What is the requirement for ESD pigeonpea in existing or potential cropping systems?
- What are the major target cropping systems of promise?
- What are the major constraints to ESD adoption and production by farmers?
- What are the prioritized researchable issues?
- How can available ESD pigeonpea production technology best be demonstrated?
- Can we propose milestones, so as to measure progress towards adoption of ESD pigeonpea in various cropping systems?
- What collaborative arrangements can be made to hasten progress in research and development of ESD pigeonpea?

The deliberations of each group are summarized below.

Improving Plant Type in Extra-short-duration Pigeonpea

Major stress factors affecting yield

Abiotic stresses.

- Rainfall during September increases flowering span, delaying maturity.
- Intermittent drought may affect yield where irrigation water is not available.
- Waterlogging at the vegetative phase is a constraint.
- In certain parts of Haryana, salinity is a constraint.
- Low temperatures at pod-filling stage may delay maturity in some seasons.

Biotic stresses.

- Insect pests: *Maruca testulalis, Grapholita (Cydia) critica, Helicoverpa armigera, Melanagromyza obtusa.*
- Cercospora leafspot, phytophthora stem blight, sterility mosaic disease.
~ Nematodes (status and extent of damage to be determined).

Plant characteristics required for adaptation and stability

- Relative insensitivity to photoperiod and temperature for wider adaptation.
- Plant height <2 m.
- Flowering that begins in the first week of September to escape heavy August rains, duration from flowering to maturity around 60 days, and maturity by 10 November. In the north-west plain zone (NWPZ), genotypes that mature by 10 November, irrespective of sowing date.
- Seed test weight at least 10 g per 100 seeds.
- Realizable yield not less than 2-2.5 t ha^{-1} in farmers' fields and able to reach 3 t ha^{-1} at experiment stations.
- Plant architecture with the following characteristics:
  semideterminate/ indeterminate;
  ability to recover rapidly from any damage to the first flush of flowers/pods;
  pods distributed over large area of the plant (longer pod-bearing);
  early growth vigor.

Work plan

- Characterization of target environments: diagnostic surveys of cropping systems, factors affecting plant stand, nature and extent of weeds and insect pests.
- Evaluation of varietal responses to sample variations in microenvironment; suggested testing sites: Hisar, Kaul, Karnal/Sonepat in Haryana; Bhatinda, Faridkot, and Ludhiana in Punjab; Delhi, and western Uttar Pradesh (Bulandshahr, Ghaziabad, Meerut).
- Screening for sensitivity to photoperiod and temperature, to be done at ICRISAT, Patancheru, and Indian Institute of Pulses Research (IIPR), Kanpur, Uttar Pradesh.
- Testing for early growth vigor, at ICRISAT and at Delhi (IARI), Hisar (Haryana Agricultural University) (HAU), Kanpur (IIPR), and Ludhiana (Punjab Agricultural University).
- Transfer of podfly resistance from long-duration (LD) pigeonpea to ESD pigeonpea by IIPR and ICRISAT.
- Sharing of segregating material and sources of resistances.
- Use of material generated under the hybrid pigeonpea program in SD/ESD group.

Improving Management of Extra-short-duration Pigeonpea Genotypes

Genotypes of 120-140 days' duration are needed, for harvesting by the first week of November, to enable timely sowing of wheat.

Sowing time

Sowing of SD/ESD pigeonpea from mid-May to mid-June, depending upon the availability of water in the NWPZ (Delhi, Haryana, Punjab, and western Uttar Pradesh). In central Uttar Pradesh, sowing with onset of monsoon rains, from the end of June to the first week of July.

Cropping systems

Pigeonpea-wheat rotation in the NWPZ of India, pigeonpea-mustard rotation in Nepal, and rice-fallow in the dry zone of Sri Lanka.

Constraints

- Poor management (plant population, weed control, drainage).
- Susceptibility to insect pests, particularly M. *testulalis, H. armigera,* and G. *critica.*
- Susceptibility to diseases, such as phytophthora blight.
- Susceptibility to abiotic stresses, such as waterlogging, salinity, and drought.

Target environments

India.

Haryana:	Bhiwani, Hisar, Mohendergarh, Rewari, and Sonepat districts.
Punjab:	Hoshiarpur, Jalandhar, Ludhiana, Patiala, Ropar, and Sangrur districts.
Uttar Pradesh:	Agra, Kanpur, and Meerut divisions.
Madhya Pradesh:	northern part.

Bangladesh. Chittagong and Rajshahi districts.

Sri Lanka. *Yala* season in the dry central zone.

Nepal. Barha, Dhanasi, Siraha, and Sirlahi districts of eastern Nepal.

Pakistan. Irrigated wheat-growing regions of Punjab and Sindh Provinces.

Collaboration

The national agricultural research systems (Bangladesh, India, Nepal, Pakistan, and Sri Lanka) and ICRISAT should collaborate; IIPR, Kanpur, needs to play a major role in strengthening the Indian national program involving its regular research centers, voluntary centers, and Krishi Vigyan Kendras in the zone. However, additional funds are needed to gear up the program.

Milestones

The following milestones to be reached in 5 years.

- Yield target of 2.5 t ha^{-1} in farmers' fields.
- Detailed studies on nature, incidence, and extent of damage from insect pests, diseases, and nematodes associated with SD and ESD pigeonpea and their appropriate management.
- Development of appropriate agronomic practices for varieties and hybrids under different cropping systems in target agroecological zones.
- Exploring of the feasibility and economics of intercropping SD and ESD pigeonpea with other upland crops.

Extension and Demonstration

Need for extra-short-duration pigeonpea varieties

There is a need for sufficient turnaround time for timely sowing of wheat in pigeonpea-wheat rotations; ESD pigeonpea holds great promise in this regard. Based on priorities, constraints, and opportunities, the following extension activities are proposed.

Training courses and target groups.

Target group	Topic of Training	Month/ duration	Implementing Agency[1]
Extension resource persons	Phenology of ESD pigeonpea varieties and critical input management	Jan/Feb 7 days	AU/ICAR/ ICRISAT
Farmers and extension functionaries			
	Crop protection	Mar/Apr 2 days	KVK/RRS
	Seeding rates, field preparation, and row spacing	Apr/May 1 day	
	Optimum plant population and thinning	May/June 1 day	KVK/RRS
	Production of good quality seed in farmers' fields	Aug 1 day	KVK/RRS

continued

Training courses and target groups, ***continued***

Target group	Topic of Training	Month/ duration	Implementing Agency[1]
	Diagnosis of irrigation need	Sep/Oct 1 day	AU/ICAR/ ICRISAT
	Diagnosis of maturity stage and postharvest care	Oct 1 day	AU/ICAR/ ICRISAT
	Postharvest technology	Nov 1 day	AU/ICAR/ ICRISAT

1. AU = agricultural universities; ICAR = Indian Council of Agricultural Research; KVK = Krishi Vigyan Kendra; RRS = Regional Research Stations.

Funding

Funds for training: for training of extension resource persons, AU/ICRISAT; for training of farmers and extension functionaries, KVK/RRS.

Surveillance

Diagnostic surveys; communication with farmers and extension functionaries on

- Insect pests
- Diseases
- Weeds
- Phosphorus, nitrogen, and zinc nutrition

General survey interval 25-30 days; at least weekly in flowering period, scouting for insect pests.
Agencies: AU/ICAR/ICRISAT in collaboration with KVK/RRS.

Demonstrations

Demonstrations should be held to acquaint farmers with ESD pigeonpea.

Type	Number	Agency
Varietal demonstrations with full package	10 (5000-1000 m^2 of each variety)	KVK/RRS
Cropping-system-oriented demonstrations pigeonpea-wheat	5 (0.4 ha size)	KVK/RRS

Funds for critical inputs-seeds, phosphatic fertilizer, and insecticides-should be arranged for the demonstrating agencies.

Field days. One or two in each varietal and crop sequence demonstration. Funds should be arranged for implementing agencies.

SAARC (South Asian Association for Regional Cooperation) exhibition of pigeonpea. A working group to be set up to explore the possibility of organizing such exhibitions.

Milestone

Official release of varieties to organize seed production program; on-farm data to be used in drafting release proposals.

Other requirements

Assembling of a monitoring group, comprised of scientists from state agricultural universities, ICAR, ICRISAT, KVK, RRS, and State Departments of Agriculture.

Cropping Systems, Seed Production, and Socioeconomic Aspects

Cropping systems

The major existing cropping systems in the NWPZ are

Pigeonpea-wheat
Rice-wheat
Sugarcane-wheat
Pigeonpea-greenpea-sugarcane-ratoon sugarcane-wheat (4-year rotation)

Constraints.

- Availability of irrigation, which has led to a shift in cropping pattern in favor of rice; irrigation policy favoring rice.
- Very high cropping intensity in the Indo-Gangetic plain, which raises questions about stability of current cropping systems.

Strategies.

- Introduction of ESD pigeonpea to improve sustainability of existing cereal-based cropping systems.
- Resource management and agronomic research to enhance stable pigeonpea production in existing cropping systems.

- Examination of comparative technical feasibility and economics of pigeonpea-potato/*toria* (a short-duration oilseed crop)-wheat rotation, rice-wheat, pigeonpea-wheat, and other rotations to maximize profit and improve sustainability of existing cropping system.
- Identification of relevant cropping zones for introduction of ESD pigeonpea.

Collaborating institutions.

- Directorate of Cropping Systems, Modipuram, to undertake research on different cropping systems.
- ICRISAT to provide elite genetic material.

Seed production

Constraints.

- Inadequacies of existing ESD pigeonpea genotypes (e.g., susceptibility to insect pests) and lack of officially released varieties.
- Low priority given to pigeonpea by seed producers.
- Lack of proper seed storage technology.
- Poor linkages amongst researchers, extensionists, seed producers, and farmers.
- The outcrossing nature of ESD pigeonpea, necessitating logistically difficult and costly precautions in seed production.
- Difficulty of maintaining purity of seed at farmers' level.

Strategies.

- Identification and release of suitable ESD pigeonpea varieties.
- Regular production of suitable ESD varieties.
- Research on seed storage methods: simple equipment, such as the 'Pusa bin'; safer pesticide use for storage.
- Transfer of technology for seed production and storage to private and public agencies and farmers.

Collaborating institutions.

- Research stations of both NARS and IARCs for breeder's seed production and supply.
- State seed farms and public sector seed companies for certified seed production.
- State agricultural universities, IARI, IIPR for seed storage techniques.
- State Departments of Agriculture (Training and Visit Division) and IIPR for popularization of appropriate seed production and storage techniques.

Socioeconomic aspects

Constraints.

- Low profitability of existing pigeonpea varieties.
- Lack of well-developed markets.
- Inadequacy of processing units in production areas.

Strategies.

- Yield enhancement of ESD pigeonpea in different cropping systems to maximize profit.
- Ensuring availability of quality seed.
- Introduction of crop insurance scheme to cover risk-yield and price uncertainties.
- More investigations to determine reasons for low profit to producers: whether such low profit is because of high assembling and processing costs or excessive margins of middlemen.
- Review of earlier studies on monopolistic (single buyer) markets and on price analysis and marketing.
- Analysis of sustainability benefits.
- Development of infrastructure for procurement, processing, and marketing.
- Information transfer to farmers.
- Delineation of target production regions for ESD pigeonpea for development of infrastructure facilities.
- Demand and supply analysis for pigeonpea.
- Evaluation of pigeonpea as an important source of household fuel needs.

Collaborating institutions.

- IARI and ICRISAT for estimating risk and uncertainty to fix premium for insurance of ESD pigeonpea.
- IARI, National Agricultural Prices Commission, and ICRISAT to estimate demand and supply and undertake price analysis of pigeonpea.
- IARI, ICRISAT, IIPR, state agricultural universities, and State Departments of Agriculture to delineate target production regions for introducing ESD pigeonpea.
- Cropping Systems Directorate of ICAR and ICRISAT to evaluate feasibility of different cropping systems.

Report on Monitoring Tour

The participants visited four on-farm trials in two villages in Sonepat District, Haryana (Satwar Singh's farm in Raipur and Ranbir Singh's farm in Sandhal Kurd), and two in Ghaziabad District, Uttar Pradesh (J P Sharma's farm in Morta and J S Verma's farm in Bhikanpur). Participating farmers from other sites also assembled at these sites and interacted with the visitors. The farmers' perceptions of the constraints and potential for ESD pigeonpea in their cropping systems are summarised here.

- ESD varieties ICPL 85010 and UPAS 120 in Ghaziabad District were sown over a period from the end of March to mid-June. March-sown plants flowered in June-July, but these reproductive branches withered away, and flowering and podding at the time of our visit was on new vegetative growth. The advantages of early sowing were considered to be better weed control and stick (stem) production for fuelwood; the disadvantages were exposure of seedlings to the hot (>45°C) summer (April-early July) and the excessive height of the crop, which hampered spraying. Grasshoppers-which were devastating adjacent sorghum, eating any emerging leaves-also girdled pigeonpea stems, causing death of younger fruiting branches. Cowbug colonies were also abundant on UPAS 120, but the contribution of these to yield loss would be difficult to ascertain.
- J S Verma had obtained average yields of 2 t ha^{-1} from ICPL 85010 since 1990, which matured by early November, in time for optimum wheat sowing by 15 November (to get 6 t ha^{-1} of wheat). Verma controls M. *testulalis* effectively by crop monitoring and only minimal spraying. Moisture response of ICPL 85010 could be seen in a gradient from an irrigation channel, with plants nearer the channel giving higher biomass and yield.

  Other observations made were poor plant stand due to early waterlogging or death after germination (caused by heat, *Rhizoctonia bataticola);* blue bull *(nilgai)* damage; weed problems (mainly *Trianthema monogyna,* locally called 'Sathy'), especially in June sowings; variability in phenology of ICPL 85010 in May sowings (inherent variability for floral initiation in this genotype, which is expressed at higher latitudes). Some farmers mentioned that it was easier to thresh determinate pigeonpea types than indeterminate ones, and that intercropping pigeonpea with maize provided better weed control and was more productive and remunerative than sole cropping of either maize or pigeonpea.
- In Sonepat District, the plantings at the sites visited were done on 25-27 June. Unusually heavy rains in the crop season caused waterlogging and delayed weeding. Farmers felt that weed management is easier and better in late May or early June sowings.

In general, the farmers recognized that ESD pigeonpea would enable timely sowing of wheat. The difficulties of obtaining good quality seed, optimum plant population, and weed and insect pest control remain. However, the declining water table is also causing concern about the sustainability of the rice-wheat system; hence pigeon-pea-wheat rotations are becoming increasingly attractive, enhanced by prevailing high prices of pigeonpea (Rs 16-18 kg^{-1}) to the farmer.

Subsequently, the yields from some of the on-farm trials were compiled from Ghaziabad and Sonepat Districts; Table 1 summarizes these. Grain yields generally were disappointing in the 1995 season, because of floods and ineffective insect pest control (these aspects will be attended to in the planning of the 1996 program).

Table 1. Yield (t ha^{-1}) of extra-short-duration pigeonpea ICPL 85010 and short-duration controls in on-farm trials, Sonepat district Haryana, and Ghaziabad district Uttar Pradesh, India, rainy season 1995.

Date of sowing	Yield		Date of harvest	
	ICPL 85010	Control	ICPL 85010	Control
Ghaziabad district				
13 May	1.2	1.1 (UPAS 120)	6 Nov	16 Nov
16 Jun	1.5	1.0 (UPAS 120)	6 Nov	12 Nov
27Jun	1.0	0.7 (UPAS 120)	25 Nov	6 Dec
12 Jun	0.9	0.7 (UPAS 120)	30 Oct	16 Nov
10 Jun	1.1	1.1 (Manak)	2 Nov	11 Nov
4 Jun	1.1	1.0 (ICPL 151)	27 Oct	5 Nov
9 Jun	1.7	1.8 (ICPL 88034)	8 Nov	15 Nov
10 Jun	1.3	1.2 (UPAS 120)	19 Nov	27 Nov
Mean	1.2	1.1		
Sonepat district				
	ICPL 85010	Control (Manak)		
27 Jun	1.5	1.4	18 Nov	2 Dec
27 Jun	1.4	1.3	18 Nov	2 Dec
25 Jun	1.3	1.2	15 Nov	28 Nov
25 Jun	1.3	1.2	15 Nov	28 Nov
Mean	1.4	1.3		

Workshop participants look at extra-short-duration pigeonpea in farmers' fields, Haryana, India.

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Acronyms and Abbreviations

ACT	Arhar Coordinated Trials
AICPIP	All India Pulses Improvement Project
AU	Agricultural universities
BARI	Bangladesh Agricultural Research Institute
BLSSC	bacterial leaf spot and stem canker
CLS	cercospora leaf spot
CMS	cytoplasmic male sterility
CSB	colletotrichum stem blight
CCSHAU	Chaudhary Charan Singh Haryana Agricultural University
CZ	central zone
DRR	dry root rot
EACT	Early Arhar Coordinated Trials
ESD	extra-short-duration
EXACT	Extra-early Arhar Coordinated Trials
FAO	Food and Agriculture Organisation of the United Nations
FCRDI	Field Crops Research and Development Institute (Sri Lanka)
FLD	Frontline Demonstrations
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDM	integrated disease management
IIPR	Indian Institute of Pulses Research (Kanpur)
IPM	integrated pest management
KVK	Krishi Vigyan Kendra
LD	long-duration
MD	medium-duration
NAPC	National Agricultural Prices Commission
NARC	National Agricultural Research Centre
NARS	national agricultural research system
NORP	National Oilseeds Research Program
NPV	nuclear polyhedrosis virus
NWFP	North-west Frontier Province
NWPZ	north-west plain zone
PAU	Punjab Agricultural University
PB	phytophthora stem blight
PM	powdery mildew
RARS	Regional Agricultural Research Station
RRA	rapid rural appraisal
RRS	Regional Research Station
SAARC	South Asian Association for Regional Cooperation
SD	short-duration
SMD	sterility mosaic disease

SZ	southern zone
USDA	United States Department of Agriculture

About IARI

Originally established in 1905 at Pusa, Bihar, with the financial assistance of an American philanthropist, Henry Phipps, the Indian Agricultural Research Institute (IARI) has been functioning from New Delhi since 1936 when it moved to its present site after a major earthquake damaged the Institute's building at Pusa. The Institute's popular name 'Pusa Institute' traces its origin to its first location.

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The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

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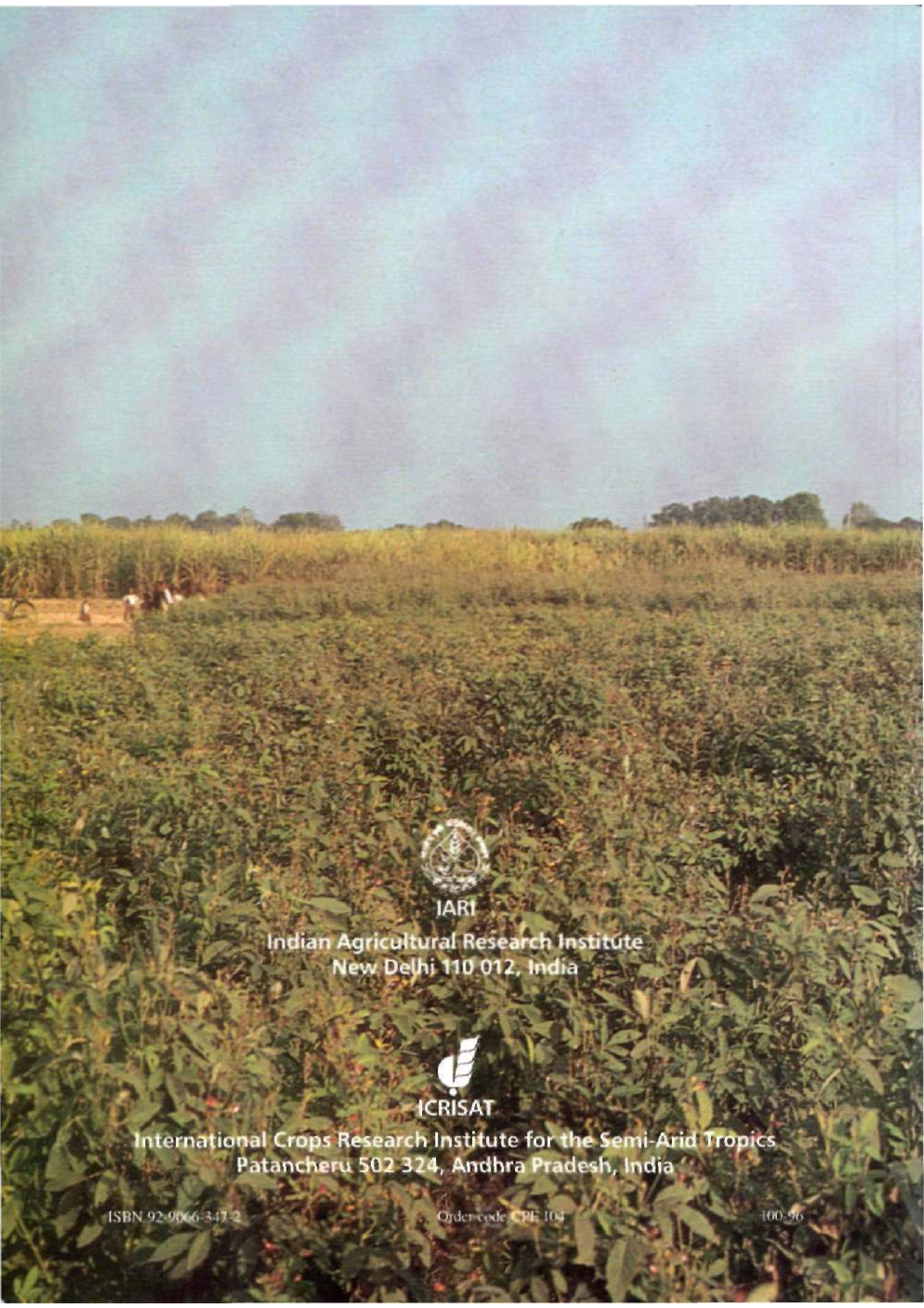
ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.



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