International Chickpea and Pigeonpea Newsletter

No. 8

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International Chickpea and Pigeonpea Newsletter

Publishing objectives

The International Chickpea and Pigeonpea Newsletter (ICPN) is published annually by ICRISAT. It is intended as a worldwide communication link for all those who are interested in the research and development of chickpea (*Cicer arietinum* L.), and pigeonpea (*Cajanus cajan* (L.) Millsp.), and their wild relatives. Though the contributions that appear in ICPN are peer-reviewed and edited, it is expected that the work reported will be developed further and formally published later in refereed journals. It is assumed that contributions in ICPN will not be cited unless no alternative reference is available.

ICPN welcomes short contributions (not exceeding 600 words) about matters of interest to its readers.

What to contribute?

Send us the kind of information you would like to see in ICPN.

- **Contributions should be current, scholarly, and their inclusion well-justified on the grounds of new information.**
- Results of recently concluded experiments, newly released varieties, recent additions to germplasm collections, etc.
- Genome maps and information on probe-availability and sequences, and populations synthesized for specific traits being mapped. Glossy black and white prints of maps should be included, if possible. Partial maps can also be submitted.
- Short reports of workshops, conferences, symposia, field days, meetings, tours, surveys, network activities, and recently launched or concluded projects.
- Details of recent publications, with full bibliographic information and 'mini reviews' whenever possible.
- Personal news (new appointments, awards, promotions, change of address, etc.)

How to format contributions?

- Keep the items brief—remember, ICPN is a newsletter and not a primary journal. About 600 words is the upper limit (no more than two double-spaced pages). **As the newsletter is devoted to the chickpea and pigeonpea crops, authors should refrain from providing a general introduction to these crops, except if they are being grown in a new area.**
- If necessary, include one or two small tables (and no more). Supply only the essential information; round off the data-values to just one decimal place whenever appropriate; choose suitable units to keep the values small (e.g., use tons instead of kg). Every table should fit within the normal typewritten area of a standard upright page (not a 'landscape' page).
- Black-and-white photographs and drawings (prepared in dense black ink on a white card or a heavy-duty tracing paper) are welcome—photocopies, color photographs, and 35-mm slides are not. Please send disk-files (with all the data) whenever you submit computer-generated illustrations.
- Keep the list of references short—not more than five references, all of which should have been seen in the original by the author. Provide all the details including author/s, year, title of the article, full title of the journal, volume, issue, and page numbers (for journal articles), and place of publication and publishers (for books and conference proceedings) for every reference.
- Express all the quantities only in SI units. Spell out in full every acronym you use.
- Give the correct Latin name of every crop, pest, or pathogen at the first mention.
- Type the entire text in double spacing. Please send a file, which should match the printout, on a double-sided/high density IBM-compatible disk using **Microsoft Applications**.
- Contact the Editor for detailed guidelines on how to format text and diskettes.
- **Include the full address with telephone, fax, and email numbers of all authors.**

The Editors will carefully consider all submitted contributions and will include in the Newsletter those that are of acceptable scientific standard and conform to requirements. The language of the Newsletter is English, but where possible, articles submitted in other languages will be translated. Authors should closely follow the style of the reports in this issue. Contributions that deviate markedly from this style will be returned for revision, and could miss the publication date. Communications will be edited to preserve a uniform style throughout the Newsletter. This may shorten some contributions, but particular care will be taken to ensure that the editing will not change the meaning and scientific content of the article. Wherever substantial editing is required, a draft copy of the edited version will be sent to the contributor for approval before printing.

Contributions and requests for inclusion in the mailing list should be mailed to:

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From the Editors

In this, the eighth issue of ICPN, there is increasing evidence of the importance that chickpea and pigeonpea are assuming outside of their traditional areas of production. China is the world's most populous nation, and Chinese researchers are actively engaged with the pigeonpea crop not only for food, but also fodder and soil conservation. In South Africa pigeonpea was hardly known, but there is interest in the crop because of its ability to grow in marginal areas, and because it is such an excellent species for intercropping. Chickpeas are also making their mark, especially the expansion of kabuli production to areas where the higher value kabuli types were not previously grown. Researchers in the traditional growing areas have not been idle either. The identification of the causal agent of pigeonpea sterility mosaic is an exciting development demonstrating the strength of partnerships between different institutions. As researchers, we should be encouraged by these developments as the spread of these crops will undoubtedly increase the demand for our services as new production constraints are identified that need to be solved. The increased internationality of these crops will also stimulate the interest of investors who we rely on to fund our research. The editors would like to thank Drs Y S Chauhan, J Crouch, C L L Gowda, G Heinrich, Jagdish Kumar, N Kameswar Rao, J V D K Kumar Rao, R V Kumar, S Pande, G V Ranga Rao, L J Reddy, T J Rego, K B Saxena, N Seetharama, H C Sharma, and S D Singh.

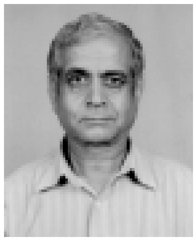
Said Silim will be handing over his editorial responsibilities to Dr H D Upadhyaya after co-editing the seventh and eighth issues. Thank you for continuing to maintain the high standards of this newsletter.

Said N Silim
Richard B Jones

News

About Scientists

R P Dua was appointed as the Project Coordinator, for the All India Coordinated Research Project on Chickpea at the Indian Institute of Pulses Research (IIPR), Kanpur, Uttar Pradesh, India.



Jagdish Kumar, Senior Chickpea Breeder and Molecular Biologist, Genetic Resources and Enhancement Program (GREP), ICRISAT was awarded Jennareddy Venkat Reddy Prize and Gold Medal by Acharya N G Ranga Agricultural University, Hyderabad, India for 1999, for his research on short-duration, fusarium wilt resistant kabuli and desi chickpea varieties, identification and naming several genes for important traits, and for the development of the first intraspecific chickpea genome map in collaboration with the Washington State University, Pullman, USA.

Jill Lenné joined as Deputy Director General (Research), ICRISAT.

Koteswara Rao was appointed as Senior Pulses Breeder at the Regional Agricultural Research Station, Lam, Acharya N G Ranga Agricultural University, Andhra Pradesh, India.

Om Gupta, Associate Professor, Department of Plant Pathology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India has been admitted as Fellow of the Indian Society of Mycology and Plant Pathology (FISMPP), Udaipur, Rajasthan, India at the 21st Annual General Body Meeting held at the Assam Agricultural University, Jorhat, Assam, India in 1999.

Om Gupta has also been nominated by the Executive Council of the Indian Phytopathological Society (IPS), New Delhi, India as 'Councillor of Central Zone' in its 53rd Annual Conference in January 2001 at Chennai, Tamil Nadu, India.

Om Gupta has also received the Best Poster Award for the paper entitled "*Bacillus subtilis*—an effective antagonist of *Rhizoctonia bataticola* (Taub.) Butler causing dry root rot of chickpea" coauthored by H K Jharia and N D Sharma. The award consisted of a memento and was presented at the National Symposium on Pulses for Sustainable Agriculture and Nutritional Security organized by the Indian Society of Pulses Research and Development (ISPRD), IIPR, Kanpur, held in New Delhi, India from 17 to 19 April 2001. Om Gupta has also been conferred as "Fellow" of the society (FISPRD).

N P Saxena, Senior Scientist, Crop Physiology (Chickpea) retired from ICRISAT on 30 June 2000. Currently, he is a Consultant Scientist, Genetic Resources and Enhancement Program (GREP), ICRISAT, working on an ICRISAT-RF-Rice special project on field phenotyping of rice under managed drought conditions. His address: Crop Physiologist/Breeder, PI-ICRISAT-RF-Rice Phenotyping Sub-project, GREP, ICRISAT, Patancheru 502 324, Andhra Pradesh, India; and e-mail ID: n.saxena@cgiar.org.

ISPRD Recognizes ICRISAT scientists

The Indian Society of Pulses Research and Development (ISPRD), under the aegis of the Indian Council of Agricultural Research (ICAR) recently awarded eminent scientists for their outstanding contributions to research and development of pulse crops.

K B Saxena *(left)* and Y S Chauhan *(middle)* are among six scientists who were conferred with the "ISPRD Recognition Award". Saxena and Chauhan were recognized for their outstanding contributions in the fields of plant breeding and pulse physiology respectively.

ICRISAT's former Deputy Director General, Y L Nene *(below left),* Founder Chairman of the Asian Agri-History Foundation was honored with the ISPRD Gold Medal for his outstanding contributions in the field of pulses research and development. This is the first time that ISPRD has instituted the Gold Medal and Nene is one of the first two recipients. The citation stated that "Dr Nene is today recognized internationally as a stalwart in agriculture, a leader in grain legumes research, and an authority in pulses pathology."

R S Paroda, Director General, ICAR, presented the awards during the inaugural session of the National Symposium on Pulses for Sustainable Agriculture and Nutritional Security, held from 17 to 19 April 2001 in New Delhi, India.

New Varietal Releases in 2000

Shasho, a kabuli type in Ethiopia (ICCV 93512).

Dilaji, in Assam, India (ICCV 89314).

PKV Kabuli-2 (KAK 2), a bold kabuli in Central Zone in India (ICCV 92311).

GCP 105, in North-East Plain Zone (NEPZ) in India (ICCL 84224 × Annigeri).

BG 1053 (Chamatkar), a kabuli type in North-West Plain Zone (NWPZ) in India (selection from ICCV 3).

GG2, in Gujarat, India (selection from JG 1258 × BDN 9-3).

Chickpea Breeders' Meet

ICAR-ICRISAT Chickpea Breeders' Meet was organized on 10–11 January 2001 at ICRISAT, Patancheru, India. About 45 chickpea scientists and pulses administrators reviewed chickpea research achievements and developed plans for future collaboration. They decided that crop improvement work will be strengthened and increased emphasis will be given on basic and molecular marker research.

Pigeonpea Production Training Course

The Training Course on Pigeonpea Production Technologies was held from 10 to 12 July 2001 in Mulanje, Malawi. About 55 field technicians from Malawi and Mozambique participated in the course. The course was sponsored by the ICRISAT/DARTS/USAID Project on Groundnut and Pigeonpea in Malawi.

Cereals and Legumes Asia Network: Future Plans

Cereals and Legumes Asia Network (CLAN) is a research and technology network among Asian countries, facilitated by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). CLAN is a network of the NARS (national agricultural research systems) by the NARS, and for the NARS. The Coordination Unit (CU) is based at Patancheru, India and supported by

ICRISAT. The core members in CLAN are Bangladesh, China, India, Indonesia, Iran, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam, and Yemen. CLAN also responds to requests from non-member Asian countries, depending on the need and interest.

The Asian Development Bank (ADB), Philippines supported the network activities since its inception in 1986 until 1999. In a Special Evaluation Study conducted during May–June 2000 by ADB, achievements of networks were highlighted: "Networking is an important sector of Agriculture and Natural Resources Research where NARS can obtain exotic breeding materials/research fundings and to conduct adaptive research under the guidance and advice of IARCs." ADB has rated the performance of CLAN as very good for its impact in the member countries. For example:

- Adoption of high-yielding, short-duration chickpea in the rice-fallows of Barind region in Bangladesh has resulted in >10,000 ha chickpea cultivation.
- In Vietnam, area under groundnut has increased from 201,400 ha to 259,000 ha in 1998. Average yield has increased from 1.04 t ha^{-1} in 1990 to 1.43 t ha^{-1} in 1998.
- Collaborative breeding programs between ICRISAT and NARS have enabled the breeders to develop, test, and release improved varieties and hybrids. More than 180 cultivars derived from ICRISAT-supplied germplasm and breeding materials have been released by Asian NARS.

Current Activities

During the CLAN Steering Committee Meeting (7–10 Dec 1999), the Country Coordinators had strongly endorsed continuation of CLAN as a linking force and vehicle for technology exchange. In the absence of donor funding, NARS have committed to support in-country R&D activities, but requested ICRISAT to provide support for coordination, exchange of germplasm and technologies, training, and meetings. ICRISAT agreed to provide the services and approached the Asia-Pacific Association of Agricultural Research Institutions (APAARI) for supplementary funds. APAARI has kindly agreed to provide limited funding from 2001. The highlights of activities during 2000 are summarized.

Exchange of germplasm and breeding material. ICRISAT gene bank supplied 622 sorghum, 1010 pearl millet, 1738 chickpea, 1002 pigeonpea, 1862 groundnut, and 59 small millet germplasm accessions to 12 Asian countries for use by national program scientists.

The following breeding material was also provided for evaluation and local selection:

Sorghum	-	17 trials and 5486 breeding lines to 11 countries.
Pearl millet	-	20 nurseries and 3139 breeding lines to 5 countries.
Groundnut	-	34 trials and 465 breeding lines to 8 countries.
Pigeonpea	-	18 trials and 339 breeding lines to 7 countries.
Chickpea	-	81 nurseries and 1092 breeding lines to 8 countries.

The materials distributed include two special trials containing promising varieties provided by network member countries for exchange with other countries:

1. Asian Regional Sorghum Varietal Adaptation Trial (26 entries + 4 checks).
2. Asian Regional Groundnut Varietal Nursery (8 entries + 2 checks).

Human resource development. During Oct 1999 to Sep 2000, 185 NARS scientists and technicians were associated with various human resource development activities at ICRISAT. This included 58 visiting scholars (junior and mid-level scientists), 55 research scholars (MSc and PhD thesis research students), 7 in-service participants (technicians), and 45 apprentices (graduate students doing project work).

Two training courses (one on database management for watershed research, and another on information technologies for librarians) were also organized.

Exchange visits of scientists. Thirty-seven scientists from three countries visited ICRISAT or participated in meetings and training programs supported by ICRISAT. On the other hand, ICRISAT scientists made 58 visits to 14 countries to participate in meetings, workshops, and monitoring visits.

Future Plans

With support from ICRISAT and APAARI, CLAN will continue to help the member countries as enumerated below:

- Support to regional varietal nursery/trial to exchange elite material among member countries.

- Supply of germplasm and breeding material to strengthen breeding programs in NARS.
- Training of NARS scientists (short term) in the areas of on-farm research, geographical information system (GIS) and remote sensing, integrated pest management (IPM), and research management.
- Support to technical meetings in Asia for exchange of technologies and to plan collaborative research.

Conclusions

The interest and commitment of member countries to continue the network for mutual benefit is heartening. Responding to the needs of the NARS, both ICRISAT and APAARI have continued to provide support to ensure that the network remains dynamic. We will continue to scout for additional funds and it is hoped that the network will continue to coordinate technology exchange and collaborative research in the Asia region.

Causal Agent of Pigeonpea Sterility Mosaic Identified

Sterility mosaic (SM), a virus-like disease of pigeonpea (*Cajanus cajan*), has been studied for nearly 70 years, based on symptomatology, transmission by mite vector, and grafting. The relentless quest over decades for SM pathogen identification was unsuccessful, but confirmed the non-involvement of a bacterium, fungus, phytoplasma, viroid, or mite toxaemia in SM etiology. Based on symptoms and transmission properties, SM was considered as a viral disease. Until now attempts for elusive SM virus were unsuccessful. Recent work at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, in collaboration with the Scottish Crop Research Institute (SCRI), Scotland, UK, led to a breakthrough in the identification of the SM causal agent. What was baffling scientists for decades is now confirmed as a novel virus, which is named as pigeonpea sterility mosaic virus (PPSMV). This crucial finding was possible with the application of improved purification protocols and precise monitoring of products at various stages during purification.

Sterility mosaic is a major threat to pigeonpea production in the Indian subcontinent. It induces sterility (complete or partial cessation of flower production) and characteristic mosaic symptoms on leaves. The infected plants appear bushy and pale due to excessive vegetative growth, stunting, and reduction in leaf size. Yield losses due to SM occurring early in the crop growth stage can reach over 90%. This disease results in grain loss estimated at 300,000 t, valued at >US$ 150 million per annum in India alone. The causal agent of SM is transmitted naturally by an arthropod mite vector, *Aceria cajani*, and experimentally by grafting, but not by mechanical sap inoculation. Cultivating SM resistant pigeonpea varieties is the most suitable option to contain the disease and enhance grain yield. Collaborative work between ICRISAT and the Indian Council of Agricultural Research (ICAR), resulted in the identification of several pigeonpea varieties with field resistance to SM infection. Most of these genotypes offered location specific resistance. But this resistance does not amount to immunity and in some can be overcome under high inoculum pressure or adverse environmental conditions. Lack of diagnostic techniques for SM agent detection and scarce information on disease epidemiology hampered breeding programs affecting precise selection of durable SM resistant sources and development of effective disease management strategies. Thus, seven decades after SM description and identification of host-plant resistance, SM, the “green plague” of pigeonpea, has remained the number one and incomprehensible problem of pigeonpea.

Research was renewed in late 1996 with a grant from the United Kingdom Department for International Development (DFID); ICRISAT and SCRI initiated work to understand the factors contributing to breakdown of resistance. This study during 1996–99, using advanced molecular biological methods and nuclear ribosomal DNA fingerprinting techniques confirmed that there is no biodiversity in the mite vector and that the variability in resistance observed at different locations is due to occurrence of SM pathogen strains and host interaction. In 1998–99, application of novel purification procedures for the SM pathogen isolation resulted in consistent detection of a 32 kDa protein in purified preparations of infected plants. Further careful studies revealed that the pathogen is a nucleoprotein containing 6 RNA species of size 3.5–1.0 kb, confirming its viral nature and it was named PPSMV. The purified virus particles are highly flexuous thin filaments of 3–5 nm in diameter. In ultrathin sections of infected tissue quasi-circular double membrane-bound bodies (DMBs) similar to those reported for other mite-transmitted diseases of unknown etiology were detected. Partial characterization by sequencing of PPSMV protein and genome detected no similarities with any other virus confirming its novelty. Antiserum was produced to the virus particles and showed its ability to detect the virus in all the naturally infected plants tested from various SM-endemic locations and also in plants inoculated under experimental conditions with mites and by grafting, confirming PPSMV association with the disease.

PPSMV until recently remained evasive because of perplexing properties, which could easily be interpreted as spurious. The features that form the basis for virus identification during initial stages of characterization process are particle morphology, size and number of structural proteins and genome. Even for highly labile viruses described till now, these properties form a reliable base and would lead to precise identification. In case of PPSMV, the purified particles are extremely unstable in vitro and always associated with some host proteins, in particular 'Rubiso'. The particle morphology is inconsistent. The particles look quite unlike conventional virus particles and often resemble host protein aggregates and thus escape detection. The number of viral genome segments and concentration differ in various purified preparations. The consistent detection of 32 kDa protein in infected plants formed main basis for the success of recent efforts. Though the protein nature was unclear for months, amid host proteins, it was distinct as a disease-specific protein in preparations from SM-affected plants and anchored research till specific protocols were established, which eventually provided insights into the nature of one of the most elusive viruses of the 20th century.

The vital knowledge on SM pathogen has already led to the development of efficient monitoring and screening technologies. A simple and cost effective enzyme-linked immunosorbent assay (ELISA)-based diagnostic test was developed for sensitive and unambiguous PPSMV detection in diseased plants. This assay is being routinely used in combination with improved screening techniques developed for precise identification of elite pigeonpea genotypes with broad-based durable resistance. Work is now in progress towards molecular characterization of PPSMV to understand its taxonomic status and its diversity in the endemic areas. The breakthrough in SM pathogen identification and information on its strains signal a major step towards an efficient approach to manage SM and will contribute to sustainable and environmentally sound methods of pigeonpea production and enhance income of pigeonpea-growing farmers in the subcontinent.

(Note: Some of these various findings have been or will be shortly published.)

Contributed by: P Lava Kumar, ICRISAT; A T Jones, SCRI; and D V R Reddy, ICRISAT.

Research Reports

Chickpea

Breeding

Dilaji: A New Chickpea Variety for Hills Zone of Assam, India

A Roy[1], K Das[1], Jagdish Kumar[2], and **B V Rao[2]**
(1. Regional Agricultural Research Station, Assam Agricultural University, Diphu 782 460, Assam, India; 2. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India)

Chickpea (*Cicer arietinum*) is a new pulse crop in the Hills Zone of Assam (India) comprising two hilly districts namely Karbi Anglong and North Cachar Hills. Shifting cultivation (locally known as *jhum*) is the predominant practice carried out in the hilly slopes of the region. Chickpea can be grown successfully in the plains and also in the slightly slopy lands (up to 20% slope) of the region.

Twenty chickpea advanced lines and controls were evaluated for various quantitative and qualitative traits including yield during 1991/92 to 1997/98 at the Regional Agricultural Research Station, Assam Agricultural University, Diphu, Assam. Diphu is located at 25°50' N, 90°30' E, and 180 m above mean sea level under rainfed conditions. Of the lines tested, ICCV 89314 was more promising for seed yield than control varieties C 235 and PBG-1.

ICCV 89314 performed better than both the controls, C 235 and PBG-1, in the multilocational trials conducted at three locations of the Hills Zone during rabi

Table 2. Fusarium wilt incidence and pod borer reactions of chickpea variety Dilaji during 1992/93 to 1994/95 in Diphu, Assam, India.

	Fusarium wilt (%)		Pod borer damage (score)[1]	
Year	Dilaji	C 235 (control)	Dilaji	C 235 (control)
1992/93	30	30	5	3
1993/94	34	37	5	5
1994/95	22	28	5	5

1. Recorded on 1–9 scale where 1 = no damage or resistant, and 9 = 100% damage or susceptible.

Table 1. Performance of chickpea variety Dilaji in various trials in Diphu, Assam, India during 1992–98.

			Yield (t ha^{-1})		
Name of trial	Year	No. of trials	Dilaji	C 235 (control)	PBG-1 (control)
Varietal Trial (Research center)	1992/93 to 1994/95	3	1.59	1.11	1.12
Agronomic Trial (Research center)	1996–98	3	0.84	–	–
Adaptive trial (Department of Agriculture Farm)	1995/96	3	1.13	0.34	0.76
Adaptive trials (Farmers' fields)	1995/96	29	1.54	1.13	–
Frontline Demonstration	1996/97	3	1.57	1.24	–
Weighted mean			1.46	1.07	0.94

Table 3. Mean performance for agronomic traits of chickpea variety Dilaji and control varieties during 1992/93 to 1994/95 under rainfed conditions in Diphu, Assam, India.

Variety	Days to maturity	Plant height (cm)	Primary branches plant^{-1}	Pods plant^{-1}	100-seed mass (g)	No. of seeds pod^{-1}	Protein content (%)
Dilaji	126	52	2–5	95	16.78	1.1	19.0
C 235	132	61	2–4	77	13.36	1.0	18.2
PBG-1	129	60	2–4	62	13.82	1.0	18.5

(postrainy season) 1996/97. On the basis of results of both on-station and on-farm trials ICCV 89314 was recommended for the zone and has been released by the State Variety Release Sub-committee as 'Dilaji'. This line was developed from the cross ICCL 80074 × ICCC 30 at ICRISAT, Patancheru, India using bulk-pedigree method and its selection number was ICCX-810098-BP-BP-77P-BP. The flower is pink; the seed is brown and angular. Anthocyanin pigmentation is present in the stem, branches, and leaves.

The yield performance of Dilaji was evaluated in various trials conducted in the zone. Dilaji produced an average yield of 1.46 t ha^{-1} while C 235 gave 1.07 t ha^{-1} and PBG-1 produced 0.94 t ha^{-1} (Table 1).

There was no significant difference in fusarium wilt incidence and pod borer reaction of Dilaji and the control variety (C 235) (Table 2). But Dilaji was promising for other quantitative traits. The protein content of Dilaji was high (19.0%) (Table 3). Therefore, this new desi variety offers a better opportunity to the farmers of the Hill Zone for adopting double cropping to augment their economic growth and also increase the total pulse production of the region.

Development of a Short-duration Chickpea for the Subtropics

Jagdish Kumar[1], R K Pannu[2], and **B V Rao[1]** (1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India; 2. CCS Haryana Agricultural University, Hisar 125 004, Haryana, India)

The success of short-duration chickpea (*Cicer arietinum*) varieties in tropical environments in India and Myanmar could be repeated in subtropical regions if short-duration genotypes are developed which tolerate/escape major abiotic and biotic stresses prevalent under these environments (Kumar et al. 1996). Saxena et al. (1997) described various abiotic stresses of chickpea in tropical and subtropical environments. A super early chickpea ICCV 96029 was developed at ICRISAT (Kumar and Rao 1996). This genotype was tested for two years (1997/98 and 1998/99) along with long-duration controls C 235 and Pant G-114 at ICRISAT, Patancheru (18° N) and CCS Haryana Agricultural University, Hisar (29° N), India respectively. The weather at Patancheru is warmer than at Hisar; this resulted in acceleration of development and crop maturity at Patancheru. The crop was planted in mid-October at Patancheru and in the beginning of November at Hisar.

The phenology data indicate that the super early genotype ICGV 96029 flowered 37 and 40 days earlier and matured 30 and 27 days earlier than controls at Patancheru and Hisar respectively (Table 1). The large difference between flower initiation and pod setting at Hisar is due to very low temperature (<5°C). Also, ICCV 96029 might have some mechanism of cold tolerance so that it was able to produce pods even in January as compared to Pant G-114 which started podding only in February. The duration of reproductive phase of ICCV 96029 is 7–13 days longer than the controls, which helped it to develop better sink that resulted in higher harvest index. The productivity in terms of seeds produced per unit time was also high in ICCV 96029 because of its short maturity duration.

ICCV 96029 may produce relatively high yields in subtropical environments represented by Hisar by escaping end-of-season stresses such as drought, pod borer damage, and leaf diseases. Kumar et al. (1996) suggested such an approach to realize increased productivity in subtropical environments. At Hisar, ICCV 96029 matured in mid-March when the weather was comparatively cooler (which helps in better sink development), and there was low incidence of pod borer. Pant G-114 matured under much warmer temperature in mid-April. The development of the short-duration, super early genotype ICCV 96029 could be useful for planting land vacated by late-maturing

Table 1. Performance of super early chickpea ICCV 96029 and long-duration controls at ICRISAT, Patancheru and CCS Haryana Agricultural University, Hisar, India 1997/98 and 1998/99.

	Patancheru[1]		Hisar[2]	
Character	ICCV 96029	C 235	ICCV 96029	Pant G-114
Days to first flower	24 ± 1.0	61 ± 0.5	43 ± 2.0	83 ± 3.0
Days to first pod	29 ± 0.5	69 ± 0.0	75 ± 4.0	107 ± 4.0
Days to maturity	79 ± 1.0	109 ± 3.5	128 ± 3.0	155 ± 2.0
Reproductive phase (days)	55 ± 2.0	48 ± 4.0	85 ± 4.0	72 ± 5.0
Plant height (cm)	40 ± 1.5	46 ± 6.0	54 ± 2.0	45 ± 6.0
Seed yield $plant^{-1}$ (g)	14 ± 5.6	21 ± 4.7	17 ± 2.0	16 ± 4.0
Biomass $plant^{-1}$ (g)	–[3]	–	43 ± 4.0	48 ± 9.0
Harvest index (%)	–	–	40.0	33.0
Productivity $plant^{-1}$ day^{-1} (g)	0.18 ± 0.03	0.19 ± 0.04	0.13 ± 0.02	0.10 ± 0.03
Seed yield (kg ha^{-1})	1022 ± 84.0	1439 ± 222.5	1042 ± 58.0	2049 ± 166.0

1. Mean of two environments.
2. Mean of three environments.
3. Data not recorded.

rice (*Oryza sativa*) and cotton (*Gossypium* sp) which otherwise remains fallow. This genotype may also hold promise as a catch crop between early maturing rice and wheat (*Triticum aestivum*), the most prevalent cropping system in northwestern parts of India. At present ICCV 96029 is the best source of earliness and can be used in breeding programs. The seed of this genotype is maintained at the Genetic Resources and Enhancement Program (GREP) of ICRISAT and is available on request.

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Desierto 98 and Tequi 98: New Kabuli Chickpeas for Northwestern Mexico

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The area of kabuli chickpea (*Cicer arietinum*) in Mexico is 120,000 ha; the average yield is 1.5–1.8 t ha^{-1}. Kabuli chickpea is cultivated in the states of Sonora (20%), Sinaloa (75%), and Baja California South (5%). About 90% of chickpea is grown with irrigation and 10% on residual moisture. The chickpea crop is attacked by soil diseases such as fusarium wilt (*Fusarium oxysporum* f. sp *ciceris*) and wet root rot (*F. solani*). Good sources of resistance to diseases have been found (Muehlbauer and Singh 1987). Improved resistant varieties have been released (Sono et al. 1995). The National Institute of Agricultural and Livestock Research (INIFAP) in Mexico started a program for breeding disease resistant kabuli chickpea at the Experimental Station in Hermosillo Sonora. The ICRISAT/ICARDA desi chickpea germplasm lines, L-4294 and L-1794, which are disease resistant were crossed with local and Spanish kabuli chickpeas to develop the disease resistant kabuli varieties Desierto 98 and Tequi 98.

Desierto 98 was developed from the cross (L-1794-Mac × Sur) × Bco Lechoso made in 1986, following bulk

Table 1. Characteristics of two new kabuli chickpea varieties compared with the local check in trials in Mexico.

Character	Desierto 98	Tequi 98	Blanco Sinaloa 92[1]
Plant height (cm)	55	70	56
Basal branches (number plant^{-1})	3	4	3
Leaf type	Simple	Compound	Compound
Days to flowering	74	80	60
Days to first pod	85	88	70
Days to maturity	149	152	137
Wilt incidence (%)	5	4	20
Seed color	Light brown	White	Cream
100-seed mass (g)	63	65	64
Harvest index	36.4	44.07	47

1. Local check.

advance to F_6. Single plant selections were made in F_7, and later generations (F_8 to F_{11}) were bulked. Finally selection number IIGH.86.5-(6B)-3P-B-B-B-B was identified as a promising line. Tequi 98 was developed from the cross (L-4294-Hillo) × Bco Lechoso following bulk advance to F_5. Single plant selections were made in F_6 and later generations (F_7 to F_8) were bulked. Finally, selection number IIGH.87.32-(5B)-1P-B-B-B-B was identified as a promising line. Both varieties were tested in natural sick plots with *F. oxysporum* f. sp *ciceris* and *F. solani* at several locations. Yield trials and commercial tests confirmed the good performance in disease resistance, big seed size, and high yield compared with Blanco Sinaloa, the best control cultivar (Table 1). Based on the superior performance, these two varieteies were released in 1998 for commercial cultivation in Mexico.

Both varieties were tested in natural sick plots for two years. Plant mortality was 4–5% while the yield was 2.0–2.2 t ha^{-1} compared with the best check cultivar Blanco Sinaloa 92 which showed 20% plant mortality and yielded 1.6 t ha^{-1}. Over four years of testing, yield of Desierto 98, Tequi 98, and Blanco Sinaloa 92 were 2.1, 2.3, and 1.8 t ha^{-1}, respectively.

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Pathology

Determination of Damaging Threshold Level of Root-knot Nematode *Meloidogyne javanica* Pathotype 1 on Chickpea

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Chickpea (*Cicer arietinum*) suffers from several biotic and abiotic stresses. Among the biotic stresses, nematodes are constraints in successful cultivation of chickpea crop (Greco 1987). Two root-knot nematodes, *Meloidogyne incognita* and *M. javanica* (Mj) are key pests in the Indian subcontinent (Sharma and McDonald 1990). The present investigation was carried out during 1995–97 to determine the threshold level of *M. javanica* pathotype 1 (Mj pt1) on chickpea cultivar Dahod Yellow, at the Department of Nematology, B A College of Agriculture, Gujarat Agricultural University, Anand, Gujarat, India.

Earthen pots of 15 cm diameter were washed with water and disinfested with 4% formaldehyde (Formalin 40 EC) and filled with steam-sterilized soil (1 kg pot^{-1}). Three chickpea seeds of the susceptible cultivar Dahod Yellow were sown in each pot. On germination, plants were inoculated at 10, 100, 500, 1,000, 5,000, and 10,000 Mj pt1 second stage larvae or juveniles (J2) per plant in the rhizosphere around the stem. Uninoculated plants served as control. There were seven treatments each with six replications arranged in a completely randomized design. Plants were watered regularly. Ninety days after nematode inoculation, plants were removed and roots were washed with water. Observations were recorded on plant height, fresh shoot and root mass, number of different stages of nematode in the roots, egg masses, eggs plant^{-1} (after staining the roots in 0.1% acid fuchsin lactophenol), soil nematode population build-up, and reproduction rate. Root-knot index was

Table 1. Effect of various inoculum levels of *Meloidogyne javanica* pathotype 1 on growth and development of chickpea (cv Dahod Yellow) and on nematode multiplication[1].

Inoculum level[2] ($J2\ plant^{-1}$)	Plant height (cm)	Fresh mass ($g\ plant^{-1}$)		RKI[3]	Nematode population $plant^{-1}$				Reproduction rate[4] (pf/pi)
		Shoot	Root		Females in root	Eggs in root	Soil population	Total	
0	27.9 a	10.94 a	12.40 a	0.00 e	0 g	0 f	0 g	0 g	–
10	27.8 a	10.98 a	12.55 a	1.00 d	57 f	758 f	254 f	69 f	106.9
100	27.2 a	10.16 a	11.81 a	1.30 d	190 e	3425 e	493 e	4108 e	41.1
500	25.0 b	8.97 b	10.09 b	2.00 c	336 d	5015 d	1652 d	7003 d	14.0
1,000	22.3 c	7.11 c	6.61 c	3.20 b	527 c	9107 c	3317 c	12951 c	13.0
5,000	17.4 d	4.48 d	5.44 c	4.70 a	664 b	16505 b	5549 b	22718 b	4.5
10,000	16.6 d	4.24 d	3.61 d	5.00 a	711 a	19910 a	7939 a	28560 a	2.9
SEm	0.6	0.54	0.35	0.12	34	517	213	752	–
Year	S	S	S	NS	S	S	S	S	–
Year × Inoculum	S	NS	NS	S	S	S	S	S	–
CV (%)	3.7	8.4	12.0	14.6	5.1	9.0	2.7	6.5	–

1. Two years pooled data. Figures followed by same letters do not differ significantly at 5% level of significance according to DNMRT (Duncan's New Multiple Range Test).
S = Significant; NS = Not significant.
2. J2 = Second stage juveniles.
3. RKI = Root-knot index; 0–5 scale where 0 = no disease, and 5 = maximum disease intensity.
4. Reproduction rate = final population/initial population (pf/pi).

calculated using 0–5 rating scale, where 0 indicated no disease and 5 indicated maximum disease intensity. The data were subjected to statistical analysis using Duncan's New Multiple Range Test (DNMRT).

There was progressive decrease in plant height, and fresh shoot and root mass with increase in inoculum level of nematode (Table 1). Maximum plant growth was obtained in uninoculated plants followed by plants inoculated with 10 and 100 J2 $plant^{-1}$ but the difference was not significant. Maximum reduction in plant growth was observed when nematode population was 10,000 J2 $plant^{-1}$. An inoculum level of 500 J2 $plant^{-1}$ significantly reduced plant height, and fresh shoot and root mass compared with the check. Thus an inoculum level of 500 J2 $plant^{-1}$ appeared to be the damaging threshold level for growth and development of chickpea cultivar Dahod Yellow (Table 1).

While nematode population in root and soil increased with an increase in inoculum levels from 10 to 10,000 J2 $plant^{-1}$ the reproduction rate of nematode decreased with an increase in inoculum levels, and was maximum (106.9 times) with 10 J2 $plant^{-1}$ and minimum (2.9 times) with 10,000 J2 $plant^{-1}$ (Table 1).

Ahmed and Husain (1988) reported an inoculum level of 1000 Mj J2 $plant^{-1}$ to be the damaging threshold level on chickpea cultivar Annigeri, while 100 Mj J2 $plant^{-1}$ on chickpea cultivar C 235 was reported by Bhatti and Bhatti (1989). In our study, the threshold level was 500 J2 $plant^{-1}$. Differences in damaging threshold level may be due to variation in susceptibility of test cultivars. Proportional increase in root-knot index and reduction in nematode reproduction rate in the present study confirm the findings of Ahmed and Husain (1988).

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Interaction between *Meloidogyne javanica* Pathotype 2 and Wilt Fungus *Fusarium oxysporum* f. sp *ciceris* on Chickpea

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Among various plant parasitic nematodes, root-knot nematodes *Meloidogyne incognita* and *M. javanica*, are key pests of chickpea (*Cicer arietinum*) in the Indian subcontinent (Sharma and McDonald 1990). Upadhyay and Dwivedi (1987) reported 40% yield loss of chickpea in India due to *M. incognita*. Fusarium wilt caused by *Fusarium oxysporum* f. sp *ciceris* (Foc) is widely distributed and reported from almost all the chickpea-growing regions in the world (Haware et al. 1990). This test was conducted to study the interaction between *M. javanica* pathotype 2 (Mj pt2) and the wilt fungus Foc on chickpea cultivar Dahod Yellow during 1995/96 and 1996/97.

Earthen pots of 15 cm diameter were disinfected with 4% formaldehyde (Formalin 40EC) solution and each plot was filled with 1 kg of steam sterilized soil. Three seeds of Dahod Yellow were sown in the center of each pot after surface sterilization with 0.1% mercuric chloride for 2 min. After emergence, plants were thinned to one plant per pot. Second stage larvae of the nematode were extracted by Petridish Assembly Method (Chawla and Prasad 1974) and inoculated in the rhizosphere of each plant at 1000 larvae plant^{-1} as per treatments. The fungus (Foc) was grown on potato dexrose broth (PDB) and suspended in sterile distilled water containing 0.1% Tween 20. Each plant was inoculated with 10 ml of the fungal spore suspension containing 2.0×10^9 spores.

The treatments consisted of Mj pt2 alone, Foc alone, Mj pt2 and Foc simultaneously (Mj pt2 + Foc), Mj pt2 followed by Foc inoculation 2 wk later (Mj pt2-Foc), Foc inoculation followed by Mj pt2 inoculation 2 wk later (Foc-Mj pt2), and no nematode or fungus inoculation (control). The treatments were arranged in completely randomized design with five replications in a net house at 22±3°C daily mean temperature. Regular watering and other necessary operations were carried out throughout the experimentation. Ninety days after inoculation, plants were removed carefully, washed free of soil and used for recording observations.

Two years pooled data revealed that maximum plant height was recorded in control followed by Foc alone, Mj pt2 alone, Foc-Mj pt2, Mj pt2-Foc, and Mj pt2 + Foc treatment (Table 1). Maximum fresh mass of shoot and root was recorded in control plants while minimum was in Mj pt2 + Foc treatment. The data showed that when both organisms are present together, the damage to the host is increased.

Root-knot index (RKI) was maximum in Mj pt2 treatment and minimum in Foc-Mj pt2 treatment (Table 1). Final nematode population was maximum in Mj pt2 treatment and minimum in Foc-Mj pt2. The reduction in final nematode population over Mj pt2 alone was 54.76% in Mj pt2 + Foc, 35.73% in Mj pt2-Foc, and 64.39% in Foc-Mj pt2 treatments. Nematode reproduction rate was low in treatments with the nematode and the fungus. It was 4.47, 6.35, and 3.52 in Mj pt2 + Foc, Mj pt 2-Foc, and Foc-Mj pt2 treatments respectively. Thus there was an adverse effect of fungus on nematode development.

Plant mortality was 80% in Mj pt2 + Foc and Mj pt2-Foc, 50% in Foc-Mj pt2, and 40% in Foc alone. The results clearly indicated that Mj pt2 had certainly predisposed the host to entry of fungus easily and profusely due to nematode injury to roots, which resulted in 100% increase in plant mortality in Mj pt2 + Foc and Mj pt2-Foc treatments and 25% increase in Foc-Mj pt2 treatment over Foc alone (Table 1). We had earlier observed similar results with *M. javanica* pathotype 1 and Foc (Patel et al. 2000). Nath and Dwivedi (1980) also reported that when *M. javanica* and Foc were present together, 56% of the plants wilted after 16 days of emergence as compared to only 27% in 31 days when Foc was present alone. Increase in wilt caused by Foc in presence of *M. javanica* in chickpea was also noticed by Sevak Ram (1982). Growth of chickpea was reduced when both, *M. javanica* and Foc were present together, irrespective of whether they were inoculated simultaneously or one after another at one wk interval (Goel and Gupta 1986).

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Table 1. Interaction between *Meloidogyne javanica* pathotype 2 (Mj pt2) and *Fusarium oxysporum* f. sp *ciceris* (Foc) on growth and development of chickpea cv Dahod Yellow plants and on nematode multiplication and wilt incidence[1].

		Fresh mass (g)			Final nematode population plant^{-1}		Reproduction rate		Wilting	
Treatment[2]	Plant height (cm)	Shoot	Root	RKI[3]	Population[4] (Log x +1)	Decrease (%) over Mj pt 2	Rate[5] (pf/pi)	Decrease (%) over Mj pt2	Wilted plants (%)	Increase (%) over Foc
Control	30.8 a	13.18 a	14.02 a	0.0 d	0.000 d (0)	–	–	–	0	–
Mj pt2	24.5 b	8.65 bcd	6.76 de	4.1 a	3.990 a (9880)	–	9.88	–	0	–
Foc	25.4 b	9.90 b	11.31 b	0.0 d	0.000 d (0)	–	–	–	40	–
Mj pt2 + Foc	15.7 e	7.43 d	6.21 e	3.2 c	3.625 c (4470)	54.76	4.47	54.76	80	100
Mj pt2-Foc	17.6 d	7.77 cd	7.54 d	3.7 b	3.783 b (6350)	35.73	6.35	35.73	80	100
Foc-Mj pt2	22.2 c	8.96 bc	8.96	3.1 c	3.544 c (3518)	64.39	3.52	64.37	50	25
SEm	0.64	0.43	0.35	0.11	0.03	–	–	–	–	–
CV (%)	5.9	14.2	11.6	14.0	3.8	–	–	–	–	–

1. Figures followed by common letters do not differ significantly from each other at 5% level of significance according to DNMRT (Duncan's New Multiple Range Test).
2. See text for details.
3. RKI = Root-knot index; 0–5 scale where 0 = no disease, and 5 = maximum disease intensity.
4. Figures in parentheses are retransformed values.
5. Reproduction rate = final population/initial population (pf/pi).

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Biochemical Changes Induced by Infection of *Meloidogyne* spp in Chickpea

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Chickpea (*Cicer arietinum*) suffers from several biotic and abiotic stresses including nematodes. Among various plant parasitic nematodes, the root-knot nematodes *Meloidogyne incognita* and *M. javanica* are key pests in the Indian subcontinent (Sharma and McDonald 1990). Peroxidase and polyphenol oxidase play a vital role in defense mechanism of plants. But no report on changes in polyphenol oxidase activity due to root-knot nematode infection in chickpea is available. A study on the comparative effect of different populations of root-knot nematodes on biochemical composition of chickpea plants was undertaken.

A pot experiment was conducted during 1995/96 and 1996/97 to find out biochemical changes induced by root-knot nematodes *M. incognita*, *M. javanica* pathotype 1, and *M. javanica* pathotype 2 in chickpea. The namatode-susceptible cultivar Dahod Yellow was used. One plant per replication and five replications per treatment were tested. Uninoculated plants were kept as control. Test plants were inoculated with the second stage larvae, juveniles (J2) of each of the test nematode. Two levels of inoculum, 10^3 and 10^4 J2 plant^{-1} were used. Fresh roots of five plants under each inoculum level treatment and healthy plants were used for estimation of biochemicals after ninety days of inoculation. Estimation of peroxidase, polyphenol oxidase, total phenol, and chlorophyll content was done by procedures given by Guilbault (1976), Malik and Singh (1980), Simson and Ross (1971), and Hiscox and Israelstam (1979) respectively.

Two years pooled data indicated significant effect of infection of *Meloidogyne* spp on the biochemical constituents. Peroxidase, polyphenol oxidase, and total phenol in roots were increased while leaf chlorophyll was reduced due to nematode infection (Table 1). The higher inoculum level of 10^4 J2 plant^{-1} induced more changes than the lower level of 10^3 J2 plant^{-1}. The overall data indicated that *M. incognita* caused more changes in the biochemical content followed by *M. javanica* pathotype 2 and pathotype 1.

These results are in agreement with the findings of Siddiqui and Husain (1992) and Sarna and Trivedi (1987) who also reported increase in peroxidase and total phenol respectively due to *M. incognita* in chickpea. Decrease in chlorophyll a and b content due to increase in inoculum

Table 1. Biochemical changes induced by infection of *Meloidogyne* spp in chickpea cultivar Dahod Yellow[1].

	Enzymatic activities (units mg^{-1})			Chlorophyll content (mg g^{-1})		
Treatment[2]	Peroxidase	Polyphenol oxidase	Total phenol (mg g^{-1})	Chlorophyll a	Chlorophyll b	Total chlorophyll
Control	0.386 d	0.226 b	10.67 c	2.49 a	2.28 a	5.01 a
Mi @ 1,000 J2 plant^{-1}	0.698 ab	0.336 ab	16.30 a	1.86 c	1.75 c	3.82 c
Mi @ 10,000 J2 plant^{-1}	0.725 a	0.348 a	16.36 a	1.19 c	1.72 c	3.16 c
Mj pt1 @ 1,000 J2 plant^{-1}	0.575 c	0.294 c	13.17 b	2.11 b	2.11 b	4.44 b
Mj pt1 @ 10,000 J2 plant^{-1}	0.695 ab	0.321 abc	16.25 a	1.47 d	1.81 c	3.49 d
Mj pt2 @ 1,000 J2 plant^{-1}	0.609 bc	0.310 bc	13.34 b	2.17 b	2.15 b	4.52 b
Mj pt2 @ 10,000 J2 plant^{-1}	0.718 a	0.325 abc	16.32 a	1.42 d	1.77 c	3.40 d
SEm	0.03	0.010	0.13	0.04	0.03	0.06
Year	S	NS	NS	S	S	S
Year × Treatment	S	NS	NS	NS	NS	NS
CV (%)	2.8	6.4	2.7	5.8	4.7	4.2

1. Two years pooled data. Figures followed by same letters do not differ significantly at 5% level of significance according to DNMRT (Duncan's New Multiple Range Test).
   S = Significant; NS = Not significant.
2. Mi = *M. incognita*; Mj pt1 = *M. javanica* pathotype 1; Mj pt2 = *M. javanica* pathotype 2; and J2 = second stage larvae or juveniles.

levels of *M. incognita* was also noticed by Tiyagi and Alam (1986).

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Entomology

Traditional Medicinal Knowledge About Pod Borer *Helicoverpa armigera* in Chhattisgarh, India

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In ancient Indian literature it is mentioned that every plant and animal present on this earth are mutually beneficial (Oudhia 1999a). India is rich in biodiversity. Many rare plants and animals from India have been reported. Enormous work has been done on utilization of plants. Industrial and allelopathic uses of common plants have been reported (Oudhia and Tripathi 1999). Like plants, insects, spiders, and mites also possess medicinal properties that can be exploited for the benefits of human beings (Oudhia 1998). For example, the oil from red velvet mite *Trombidium grandissimum* is useful for paralysis. Also due to its ability to increase the sexual desire *Trombidium* is named as 'Indian Viagra' (Oudhia 1999b). The pod borer or the gram caterpillar *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) is cosmopolitan and is widely distributed in India. It is a serious pest of chickpea (*Cicer arietinum*), pigeonpea (*Cajanus cajan*), cotton (*Gossypium* sp), sorghum (*Sorghum bicolor*), okra (*Abelmoschus esculentus*), and maize (*Zea mays*). Medicinal uses of *Helicoverpa* have not been reported in the available literature. Many previous studies conducted in Chhattisgarh region in India have revealed that the native people, particularly the old villagers, have rich traditional knowledge about common insects and mites. A survey was conducted during 1998–99 to list out the information on traditional medicinal knowledge about *H. armigera*.

A detailed ethnozoological survey was conducted in Raipur, Bastar, Rajnandgaon, Durg, Mahasamund, Sarguja, Kanker, and Bilaspur districts of Chhattisgarh. With the help of a well-prepared questionnaire, common information about the pod borer was collected from 100 randomly selected villagers. Based on the responses to the questionnaire, 15 villagers (5 from Raipur, 3 from Bastar, 5 from Durg, 2 from Sarguja) having some knowledge about the medicinal uses of *Helicoverpa* were selected. Through regular visits to their villages and with the help of regular correspondences, the information on medicinal properties of *Helicoverpa* was collected.

The survey revealed that these villagers (mostly above 60 years of age) use *Helicoverpa* alone or in combination with herbal drugs to treat more than 50 common diseases. Some medicinal uses are described below. *Helicoverpa* is used with herbal drugs such as Ashwagandha (*Withania somnifera*), Safed Moosli (*Chlorophytum borivilianum*), and Satawari (*Asparagus racemosus*). Villagers use powder (after drying and crushing) of caterpillars as a tonic for many common ailments such as fever, general weakness, and nervous breakdown. They generally apply the fresh extracts of caterpillars on injured parts of the body to stop bleeding as a first aid measure. This is a common practice in Chhattisgarh region. A villager from Durg, who is also a traditional healer, uses the aqueous extracts of caterpillar to promote hair growth. It is used externally. Many villagers use powder of the caterpillars with Sanai (*Cassia obtusifolia*) as a purgative. Sanai is a reputed purgative. Addition of caterpillar to Sanai increases its effectiveness. In Chhattisgarh, *Helicoverpa* infests many common weeds. *Sphaeranthus indicus*, locally known as *gorakhmundi*, is a common weed in chickpea fields (Oudhia 1999c). *Helicoverpa* caterpillar feeding on *Sphaeranthus* leaves is used for the treatment of eosinophilia and asthama.

During the survey, the villagers complained that the new generation is not much interested in medicinal properties of common insects and mites. The survey suggested that there is a need to document the medicinal and other uses of *Helicoverpa* with the help of extensive survey. The study indicated that there is a tremendous scope in this new field of research.

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Agronomy

Responses of Chickpea Cultivars to Iron Deficiency

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In Tunisia, chickpea (*Cicer arietinum*) cultivation is localized in the north of the country. Chickpea and faba bean (*Vicia faba*) constitute the two major food legumes of Tunisia. However, yields remain low, about 700 kg ha^{-1}, probably due to its limited adaptation to calcareous soils which are frequent in this region. Presence of bicarbonates in soils often induce nutrient deficiencies such as iron deficiency. Solution containing bicarbonate and calcium carbonate are often used to evaluate, in controlled conditions, plants tolerant to iron deficiency.

The objective of this work was to study the behavior of four chickpea cultivars, largely cultivated in Tunisia, in iron deficiency conditions induced by bicarbonate.

Three local cultivars, Amdoun, Kesseb, and Chetoui, and one variety INRAT 88 [from INRAT (Institut National de Recherche Agronomique de Tunisie), Tunisia] were used in this experiment. Plants were grown in nutrient solution under conditions described previously (Sleimi et al. 1999). Iron was added as Fe{III}-Na-EDTA at 30 μM concentration.

Seedlings of each cultivar were grown in nutrient solution deprived of iron, for 8 days, and then divided in two lots; first one was transferred to the nutrient solution containing iron (30 μM), and the second one to similar solution but added with sodium bicarbonate (10 mM). After four weeks, plants were harvested and divided into leaves, stems, and roots. Leaf chlorosis was estimated according to Gildersleeve and Ocumpaugh (1989) using a scale including four levels, from 0 (no chlorosis) to 4 (severe chlorosis with some necrosis). For each plant, we asigned a number (0 to 4) according to its chlorotic

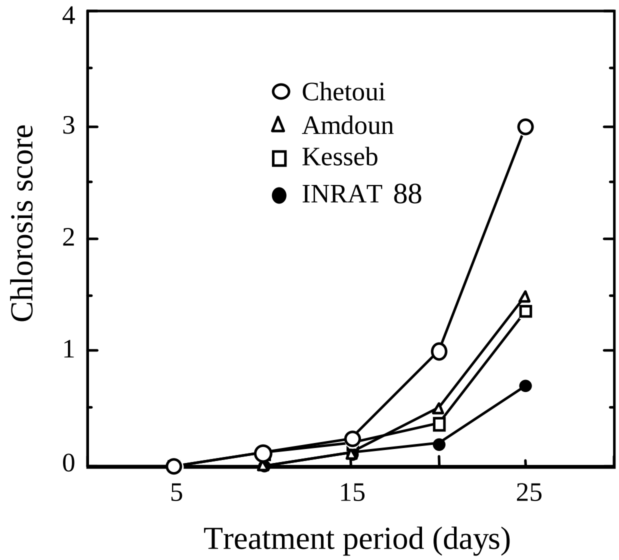

Figure 1. Chlorosis score of chickpea cultivars grown on medium containing bicarbonate (30 µM iron, 10 mM sodium bicarbonate). The severity of iron deficiency chlorosis was visually rated on 0 to 4 scale (0 = no chlorosis and 4 = severe chlorosis with necrotic spots). Each value is the mean of eight plant replications.

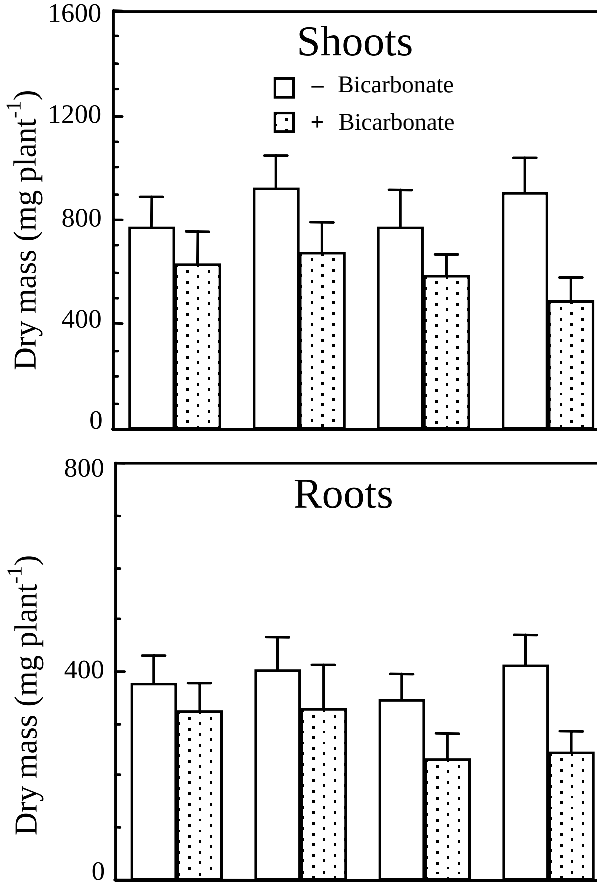

Figure 2. Effect of bicarbonate on shoot and root growth of chickpea cultivars. (Note: The values are means of eight plant replications and the vertical bars indicate SD of means.)

state. Chlorosis score was calculated as the mean number of eight plants. Total iron was extracted by the method of Grusak (1995) and analyzed by atomic absorption spectrophotometry.

At ten days after treatment, bicarbonate treated plants showed chlorosis on young leaves of Chetoui and Kesseb plants only (Fig. 1). At 25 days, iron chlorosis was severe in Chetoui (score 3), moderate in Amdoun and Kesseb (score 1.5), and light in INRAT 88 (score <1).

Bicarbonate reduced plant growth slightly in INRAT 88, Amdoun, and Kesseb (the decrease was 20 to 25% of control plants), and greatly (45%) in Chetoui (Fig. 2). Root growth of the most tolerant cultivar (INRAT 88) was the least affected by bicarbonate. These results suggest that the maintenance of root biomass in conditions of iron deficiency could be a physiological criterion for tolerance to this stress. Also, our results showed that plant growth was reduced as much as chlorosis was accentuated, cultivar Chetoui being the more affected. This indicated that decrease in growth of bicarbonate treated plants was mainly due to restricted feeding of plants with iron.

Iron analysis was done only for two cultivars, INRAT 88 and Chetoui that showed different reactions. Total iron concentration was decreased in leaves of bicarbonate treated plants of all cultivars except Chetoui which showed the most reduction in plant growth (Fig. 3). On the other hand, root growth was increased, especially in Chetoui (Fig. 3). According to Abadia et al. (1985), total iron concentration is not a good indicator of iron deficiency; iron concentration was often higher in chlorotic than in green leaves. This may be explained by the reduction of leaf growth which leads to high apparent iron concentration (Morales et al. 1998).

Iron content of plants grown in bicarbonate medium decreased in shoots and not in roots of the two cultivars (Fig. 4). This decrease was higher in sensitive cultivar (Chetoui) than in the tolerant one (INRAT 88). These

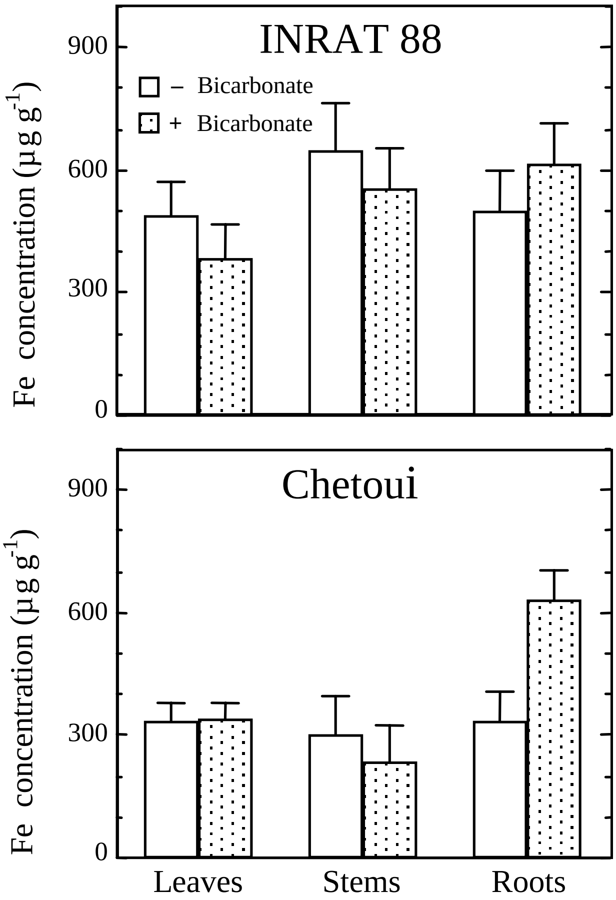

Figure 3. Iron (Fe) concentration in dried leaves, stems, and roots of two chickpea cultivars grown on medium with or without bicarbonate (10 mM) during 28 days. (Note: The values are means of eight plant replications and the vertical bars indicate SD of means.)

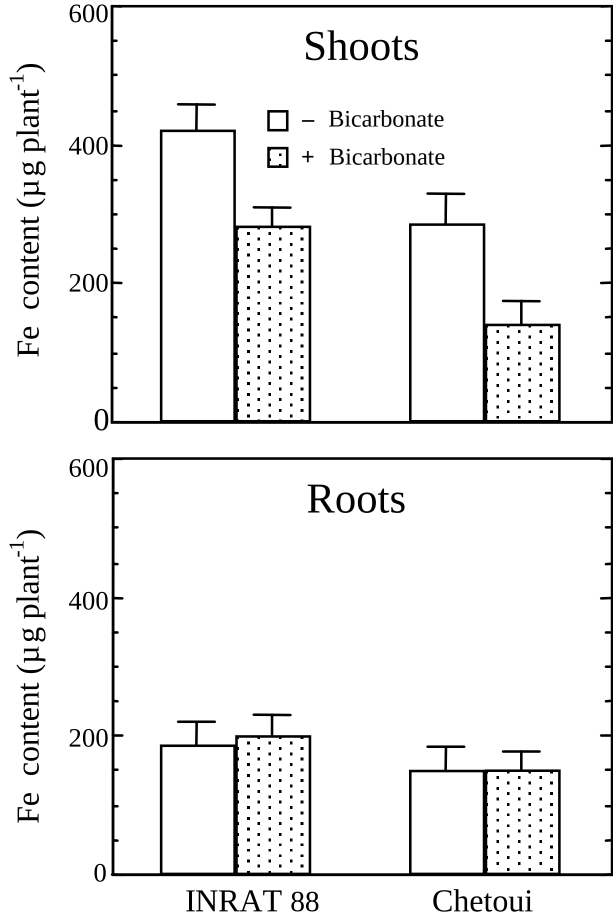

Figure 4. Iron (Fe) content in shoots and roots of the two chickpea cultivars INRAT 88 and Chetoui grown on medium with or without bicarbonate. (Note: The values are means of eight plant replications and the vertical bars indicate SD of means.)

results indicated that bicarbonate limited iron translocation to shoots, leading to iron accumulation in roots, mainly in apoplast (Grusak 1995).

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Exploiting Chickpea as an Intercrop in Sugarcane

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In the Punjab state of India, area under chickpea (*Cicer arietinum*) has reduced drastically from more than 800,000 ha in 1961 to 13,000 ha in 1998. The major factors for this decline are: (1) tough competition of chickpea with wheat (*Triticum aestivum*) crop, which is more assured and profitable than chickpea; and (2) non-availability of high input responsive varieties of chickpea. Under the present rice (*Oryza sativa*)-wheat and cotton (*Gossypium* sp)-wheat cropping system in Punjab, the only possibility to increase the area under chickpea is by its cultivation either in new or non-traditional areas or as an intercrop with winter crops. The development of a new high input responsive chickpea variety GPF2, developed at the Punjab Agricultural University (PAU) Regional Research Station, Faridkot, Punjab, India and released for cultivation in North-West Plain Zone, has opened the possibility of cultivating chickpea under high fertility and irrigated conditions. This variety can tolerate 3–4 irrigations. In the present study, we have examined the possibility of growing chickpea as an intercrop in sugarcane (*Saccharum officinarum*). In Punjab, sugarcane is planted in two seasons: spring (February–March) and autumn (September–October). Of 200,000 ha area under sugarcane, about 20% area is being covered by autumn crop. Since the growth of autumn sugarcane from October to March is very slow due to low temperature, chickpea can grow very well and generate extra income for the farmers of Punjab.

An early maturing sugarcane cultivar CoJ 83 was planted in three replications on 10 October 1998 at PAU Regional Research Station, Faridkot. Each treatment was accommodated in 5 rows of 6 m length with inter-row spacing of 90 cm. Seventy-two buds at twelve buds m^{-1} were planted in each row. The desi chickpea cultivar GPF2 was sown as an intercrop in sugarcane on 11 November 1998. The experiment comprised the following nine treatments:

T_1: Sugarcane with 225 kg nitrogen (N) ha^{-1};

T_2: T_1 + one row of chickpea with no extra fertilizer to chickpea;

T_3: T_1 + two rows of chickpea with no extra fertilizer;

T_4: T_1 + one row of chickpea with recommended fertilizers (15 kg N ha^{-1} and 20 kg P_2O_5 ha^{-1});

T_5: T_1 + two rows of chickpea with recommended fertilizers;

Table 1. Effect of different treatments on yield and yield contributing characteristics of chickpea and sugarcane at Faridkot, Punjab, India during autumn 1998/99.

	Chickpea			Sugarcane			
Treatment[1]	Pods plant^{-1}	Seeds pod^{-1}	Seed yield (t ha^{-1})	No. of tillers ('000 ha^{-1})	No. of millable canes ('000 ha^{-1})	Cane yield (t ha^{-1})	Sucrose (%)
T_1	–	–	–	189.63	124.69	108.54	15.20
T_2	187.0	1.48	1.26	157.28	121.48	103.78	15.58
T_3	197.3	1.45	1.77	153.09	117.28	86.22	15.82
T_4	168.3	1.40	1.22	165.68	119.01	107.11	15.82
T_5	191.7	1.38	2.02	123.70	105.93	99.19	16.20
T_6	176.0	1.45	1.36	158.52	120.00	103.63	16.01
T_7	172.7	1.45	1.79	148.15	105.19	83.36	15.72
T_8	134.3	1.32	1.36	156.30	120.00	103.63	16.34
T_9	136.7	1.43	1.67	129.63	112.59	86.67	16.90
CD at 5%	NS[2]	NS	0.22	24.81	NS	NS	NS
CV (%)	19.16	11.87	8.01	9.34	10.57	11.71	5.70

1. See text for details of treatments.
2. NS = Not significant.

T_6: Sugarcane with 150 kg N ha^{-1} + one row of chickpea with no extra fertilizer;

T_7: Sugarcane with 150 kg N ha^{-1} + two rows of chickpea with no extra fertilizer;

T_8: Sugarcane with 150 kg N ha^{-1} + one row of chickpea with recommended fertilizers;

T_9: Sugarcane with 150 kg N ha^{-1} + two rows of chickpea with recommended fertilizers.

The recommended fertilizer to sugarcane was applied in three equal instalments: 1/3 at the time of planting, 1/3 at the end of April, and the remaining 1/3 at the end of May. The recommended fertilizers to chickpea were applied at the time of sowing. In addition to one pre-sown irrigation, two irrigations were given to intercrop plots on 15 December 1998 and 6 March 1999. However, the sole sugarcane crop received five irrigations up to the harvest of chickpea. Total rainfall from November 1998 to April 1999 was 83.1 mm. Recommended plant production and protection practices were followed in both the crops. The chickpea crop was harvested on 22 April 1999, while the sugarcane was harvested on 15 December 1999.

The seed yield of chickpea variety GPF2 from two-rows plot was significantly higher than one-row plot of chickpea (Table 1). Differences between one row and two rows of chickpea for number of pods $plant^{-1}$ and seeds pod^{-1} were not significant. On an average, two rows of chickpea gave considerably higher seed yield (1.82 t ha^{-1}) as compared to one row of chickpea (1.30 t ha^{-1}) (Table 2). It is apparent from the results that extra fertilizer to chickpea did not increase significantly the seed yield of chickpea (Table 1), thus indicating that there is no need to apply any additional fertilizer to chickpea crop. Number of tillers in sole crop of sugarcane was significantly higher than the intercropped plots (Table 1). The reduction in number of tillers in sugarcane was higher with two rows of chickpea in comparison to one row of chickpea. Differences in cane yield and number of millable canes between sole crop of sugarcane and intercrop treatments were not significant. This may be due to the fact that when sugarcane picks up its growth in April, the chickpea crop is at harvesting stage at that time and it does not influence the growth of sugarcane. The yield of sugarcane was higher with recommended dose of N, i.e., 225 kg N ha^{-1} (T_2 to T_5) than with 150 kg N ha^{-1} (T_6 to T_9). However, the yield of chickpea was significantly higher in T_5 where 225 kg N ha^{-1} was applied to sugarcane as compared to T_9 where sugarcane received 150 kg N ha^{-1}. Panwar et al. (1990) intercropped maize (*Zea mays*), wheat, *raya* (*Brassica juncea;* Indian mustard), chickpea, and lentil (*Lens culinaris*) in sugarcane and recorded the highest number of millable canes and cane yield with lentil and chickpea as intercrops. *Raya* as an intercrop reduced considerably the number of millable canes in sugarcane. Intercropping of chickpea in sugarcane did not influence the sucrose content in sugarcane. The results of our study suggest that growing one row of chickpea as an intercrop in sugarcane can yield extra income without affecting the sugarcane yield. It is also evident from the study that if recommended dose of fertilizer, i.e., 225 kg N ha^{-1} is applied to sugarcane, then there is no need to give any extra fertilizer to chickpea for getting high productivity of both sugarcane and chickpea. Moreover, chickpea being a leguminous crop will also help in maintaining the soil health. This experiment was repeated in autumn 1999/2000 at three locations to confirm the results. The economics of both chickpea and sugarcane will also be worked out.

Table 2. Mean performance of various treatments of chickpea and sugarcane grown at Faridkot, Punjab, India during autumn 1998/99.

Treatment[1]	Seed yield of chickpea (t ha^{-1})	Cane yield (t ha^{-1})
One row of chickpea (1)	1.30	104.54
Two rows of chickpea (2)	1.82	88.86
Sugarcane with 225 kg N ha^{-1} (3)	1.57	99.08
Sugarcane with 150 kg N ha^{-1} (4)	1.55	94.32
Chickpea with no extra fertilizer (5)	1.54	94.25
Chickpea with recommended fertilizers (6)	1.57	99.15

1. 1 = Mean of T_2, T_4, T_6, and T_8; 2 = Mean of T_3, T_5, T_7, and T_9; 3 = Mean of T_2, T_3, T_4, and T_5; 4 = Mean of T_6, T_7, T_8, and T_9; 5 = Mean of T_2, T_3, T_6, and T_7; 6 = Mean of T_4, T_5, T_8, and T_9. See text for details of treatments.

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Biotechnology

Efficient Plantlet Regeneration in Chickpea

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Organogenesis in chickpea (*Cicer arietinum*) from callus culture was reported by Gosal and Bajaj (1979). Multiple shoots from apical meristem, stem nodes, and cotyledon explants were observed in chickpea by Rao and Chopra (1989). Altaf and Ahmad (1986) observed better response of multiple shoots formation from hypocotyls. Sagare et al. (1993) reported plantlet regeneration by somatic embryogenesis. This study was carried out to develop an efficient regeneration protocol in two chickpea cultivars C 235 and BG 261.

Multiple shoot production

Decapitated embryos and epicotyls excised from 3- or 4-day-old seedlings of the two chickpea cultivars were cultured on MS basal medium containing constituents of MS medium (Murashige and Skoog 1962) and vitamins of B5 medium (Gamborg et al. 1968). The pH of the medium was adjusted to 5.8 before autoclaving and the medium was solidified with 0.6% agar. Both the explants (decapitated embryos and epicotyls) were cultured on the above medium with varying concentrations of 6-benzyl aminopurine (BAP) and naphthalene acetic acid (NAA). For decapitated embryos, 2–3 mg L^{-1} BAP and 0–1 mg L^{-1} NAA were used and for epicotyls, 0–2 mg L^{-1} BAP and 0–1 mg L^{-1} NAA were used. Decapitated embryos induced multiple shoots directly with most of the hormone combinations (Table 1). In medium with 3 mg L^{-1} BAP, 100% shoots were induced. Initially there were 4–5 shoots per explant; the number of shoots on further subculturing increased to 12–15 per explant. After second cycle of subculturing the average number of shoots was 10–12 per explant. The shoot length increased to 2.5–4.0 cm at 3 weeks of subculturing. No regeneration was observed by organogenesis.

Epicotyls showed efficient direct regeneration from the cut portion in medium with BAP alone. Regeneration by organogenesis was also seen in certain BAP and NAA combinations which was maximum up to 70% at 1.0 mg L^{-1} BAP and 0.5 mg L^{-1} NAA. Hundred per cent shoots were induced at 2.0 mg L^{-1} BAP alone. The number of shoots induced was 1–3 per explant, which increased on subculturing to >5 per explant. Increase in NAA concentration in medium with 2 mg L^{-1} BAP promoted only callus induction with increase in size, but regeneration was suppressed.

Root induction

The regenerated shoots were subjected to half-strength MS salts + B5 vitamins with 1% sucrose. The media was supplemented with various concentrations of NAA and

Table 1. Effect of different hormone concentrations on callus and shoot induction from decapitated embryo explants of chickpea in MS medium with B5 vitamins[1].

Hormone concentration[2] (mg L^{-1})		Callus induction	Direct shoot regeneration[3]
BAP	NAA	(% responding explants)	(% responding explants)
2.0	0.00	0	80 (>5)
2.0	0.04	0	90 (>5)
2.0	0.50	0	70 (>5)
2.0	1.00	20	50 (1–3)
3.0	0.00	0	100 (>5)

1. Expalnts were excised from 4-day-old seedlings of chickpea cultivars C 235 and BG 261. Twenty explants per treatment were tested. Observations were recorded 4 weeks after culturing.
2. BAP = 6-benzyl aminopurine; NAA = naphthalene acetic acid.
3. Figures in parentheses are number of shoots per explant.

indole butyric acid (IBA). Both solid and liquid media were used for rooting. There was 50% rooting at 0.8 mg L^{-1} NAA in solid medium and 70% with 1.2 mg L^{-1} NAA and 0.4 mg L^{-1} IBA. The induced roots were thicker and longer in liquid medium than in solid medium.

The rooted shoots were transferred to plastics pots containing autoclaved soil:sand:compost (1:1:1) mixture, and covered with polythene bag to maintain the relative humidity. The pots were placed in growth chamber at 26°C for 16/8 hours light and dark cycle. The plantlets remained green for 10–12 days but did not get established in the soil, and eventually died. This may be due to the recalcitrant nature of chickpea and the conditions/factors provided for hardening and establishment. Efforts were made for better acclimatization of plantlets using pure vermiculite and vermiculite perlite (1:1) mixture as was used by Barna and Wakhlu (1994). This technique proved moderately successful, and the established plants were finally transferred from growth chamber to polyhouse.

Our experiments indicated that multiple shoots can be regenerated from both decapitated embryo and epicotyl explants after cutting the surface layer (which removes the preformed shoot initials). This shows that the partially differentiated cells may be present just below the excised meristems.

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Plant Regeneration from NaCl Tolerant Callus/Cell Lines of Chickpea

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In India, 7.04 million ha land is affected by salinity (Abrol and Bhumbla 1971). Chickpea is one of the foremost important pulse crops. Chickpea production is affected by salinity to a great extent in Haryana, Punjab, Rajasthan, and western Uttar Pradesh, where saline water is used for irrigation. In vitro selection of cell lines is now being used as an alternative tool to accelerate breeding programs in many crops (Singh et al. 1999). Earlier studies on this aspect resulted in isolation of sodium chloride (NaCl) adapted/tolerant cell lines of chickpea. However, regeneration from these tolerant cell lines could not be achieved due to inadequacy of the regeneration protocol. We report here regeneration of plantlets from salt adapted/tolerant cell lines of chickpea.

Embryonic axes (explants) from sterilized mature seeds of nine chickpea genotypes were excised and cultured aseptically on MS medium (Murashige and Skoog 1962) supplemented with 0.5 mg L^{-1} naphthalene acetic acid (NAA) + 0.5 mg L^{-1} 6-benzyl aminopurine (BAP) + 40 g L^{-1} sucrose and 0.8% agar for callus induction. The calli produced were further subcultured on the same medium enriched with different concentrations (0%, 0.25%, 0.5%, and 1.0%) of NaCl. Callus from each explant was maintained separately and screened against different doses of NaCl. The embryogenic calli that were multiplying/growing on stress medium were selected for three cycles at intervals of 20 days. Such selected callus pieces were designated as variant/tolerant. The growing calli were further transferred to regeneration medium without NaCl stress (MS salts + B5 vitamins + 0.125 mg L^{-1} indole butyric acid (IBA) + 2.0 mg L^{-1} BAP + 40 g L^{-1} sucrose + 0.8% agar). Tolerant regenerants were further subjected to stability test in NaCl stress medium for confirmation.

Table 1. Selection and survival of chickpea calli and regenerants against sodium chloride (NaCl).

		0% NaCl		0.25% NaCl		0.5% NaCl		1.0% NaCl	
Cycle	Days	No.	%	No.	%	No.	%	No.	%
I	20	298	100.0	244	100.0	244	100.0	236	100.0
II	40	296	99.3	152	62.3	148	60.6	78	33.1
III	60	295	98.9	149	61.1	130	53.3	50	21.2

Table 2. Recovery of stable resistant clones of chickpea in medium with different concentrations of sodium chloride (NaCl).

		Resistant clones				
		Selected		Stable		
Concentration of NaCl (%)	No. of explants (a)	No. (b)	%	No. (c)	%	No. of escapes (b−c/a) × 100
0 (control)	295	290	98.3	265	89.9	8.5
0.25	149	90	60.4	75	50.3	10.1
0.5	130	75	57.7	65	50.0	7.7
1.0	50	20	40.0	8	16.0	24.0

The stability of resistant clones was estimated by calculating the number of "escapes" in selected population as follows:

$$\text{Number of escapes} = (b-c)/a \times 100$$

where a = total number of explants, b = number of selected resistant clone(s), and c = stable clone(s).

The effect of NaCl on callus was observed as changes in color (browning) and texture (compactness). The magnitude of callus growth was dependent on the concentration of NaCl and incubation period of cultures in presence of NaCl. The control (no stress) resulted in green and friable callus, while the NaCl treatments showed varied degree of browning and necrosis depending on the concentration of NaCl used.

The recovery of salt tolerant/adapted calli decreased with increase in concentration of NaCl. The lowest recovery (21.2%) of adapted calli was observed on 1.0% NaCl, whereas maximum recovery (61.1%) was obtained on medium containing 0.25% NaCl (Table 1). In general, a substantial reduction in number of selected clones was observed after subsequent cycle of selection (direct stepwise). Further, it was observed that frequency of stable resistant clones declined substantially on increasing the dose of NaCl. Highest frequency (50.3%) of stable clones were obtained at 0.25% NaCl concentration and lowest frequency (16.0%) at 1.0% NaCl (Table 2). Pandey and Ganapathy (1984) and Gosal and Bajaj (1984) also isolated salt tolerant cell lines of chickpea. However, they failed to regenerate the tolerant cell lines. Further, Singh et al. (1999) reported regeneration of aschochyta blight resistant cell lines of chickpea. With improved regeneration protocol, it is now possible to regenerate salt tolerant cell lines in chickpea. However, the progenies of these salt tolerant plantlets need to be analyzed in order to confirm the genetic basis of salt tolerant trait.

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Prospects of Using *Cicer canariense* for Chickpea Improvement

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There are eight annual and 34 perennial wild species in the genus *Cicer* (van der Maesen 1987). Many of these wild species are known to possess resistance genes to important biotic and abiotic constraints. Wild species placed in primary and secondary gene pools are crossable by conventional techniques (Ladizinsky and Alder 1976, Pundir and Mengesha 1995). There are wild species which are placed in tertiary gene pool based on non-crossability with cultivated chickpea (*Cicer arietinum*). One of the bottlenecks for the failure to produce hybrids was the absence of a suitable technique to save aborting embryos from interspecific crosses. Recent efforts at ICRISAT, Patancheru, India have led to the development of techniques to save aborting embryos from failing crosses (Mallikarjuna 1999). As a result hybrids have been produced between *C. arietinum* and *C. pinnatifidum*.

There is no report of successfull crossing of perennial wild species with cultivated chickpea and hybrid production. Mercy and Kakkar (1975) crossed perennial wild species *C. songaricum* with *C. arietinum*, and in spite of carrying out 4200 pollinations hybrid seeds were not obtained. Pundir et al. (1993) reported that none of the perennial wild species can be successfully grown to set seeds under the environmental conditions of ICRISAT research center, except *C. canariense*, a perennial wild species from Canary Islands (Fig. 1a).

Experiments were initiated at ICRISAT to cross kabuli chickpea cv ICCV 6 and desi cv GL 769 using *C. canariense* as the male parent. Emasculations and pollinations were carried out in the morning between 8.00 am and 10.00 am. Cross pollinated flowers were tagged and an aqueous mixture of growth regulators consisting of gibberellic acid, naphthalene acetic acid, and kinetin (7:1:1) was applied to the base of the pollinated pistils five hours after pollination.

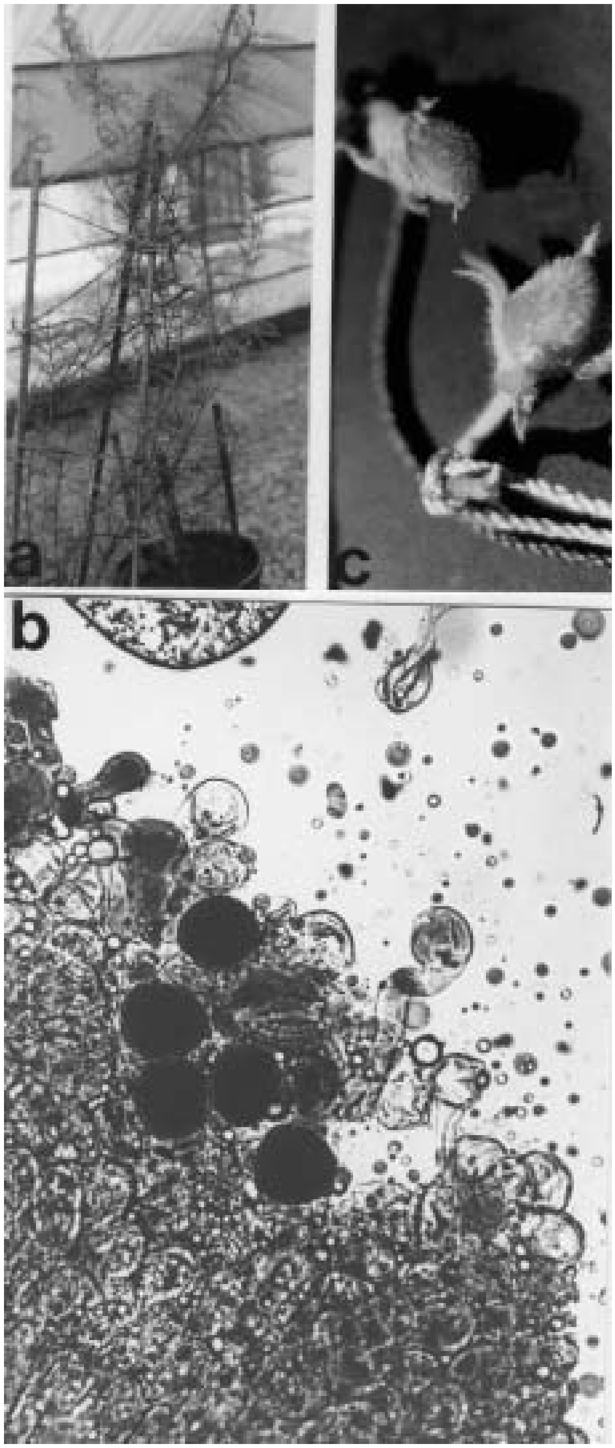

Figure 1. Interspecific hybridization between *Cicer arietinum* and *C. canariense*. a. The male parent *C. canariense* plant raised in the greenhouse. b. *C. canariense* pollen grains germinating on *C. arietinum* stigma. c. Growth regulators induced hybrid pod development in the cross *C. arietinum* × *C. canariense*.

Table 1. Success of pollinations in crosses between cultivated chickpea *Cicer arietinum* and the wild species *C. canariense*.

Chickpea cultivars	Pollinations	Pod set	Pod size (3–4 mm width)	Ovule size (1–2 mm width)
ICCV 6	25	11	6	5
GL 769	19	8	3	2

Light and fluorescent microscopic studies showed that the pollen grains germinated normally on the stigma (Fig. 1b). Swelling of the pollen tubes was rarely observed. Pod initials were observed at 6 days after pollination (DAP). By 14 DAP, yellowing of the pods was observed (Fig. 1c); hence pods were harvested at 14–18 DAP. The maximum pod size obtained was 4 mm × 4.5 mm and ovule width was 2 mm (Table 1). Pods were surface sterilized and green ovules of 2 mm width were aseptically cultured on the ovule culture medium, which consisted of ML-6 basal medium with 3% sucrose, zeatin (1.0 mg L^{-1}) and 0.25 mg L^{-1} indole acetic acid (IAA) (Mallikarjuna 1999).

Ovules did not show growth even after 45 days of culture. Ovules which were green at the time of culture had bleached. The ovules were dissected and the embryos were isolated. Globular embryos were observed. This indicated that the barrier to hybridization between *C. canariense* and *C. arietinum* was mainly post-zygotic. This is supported by the fact that pollen grains germinated normally on the stigma and development of the pod was dependent on growth regulator. In the pollinated pistils where growth regulators were not applied, development of pod initials was not observed.

About 45–50% of the pollinations do not form pods in the compatible cross *C. arietinum* × *C. echinospermum*. Hence, a large number of pollinations is a requisite for the success of a cross involving wild species of chickpea. In the crossing experiment involving the annual incompatible wild species *C. pinnatifidum*, large number of cross pollinations resulted in many hybrid pods but only few aborting ovules were large enough for culture and pod formation was dependent on growth regulators (Mallikarjuna 1999). Paucity of *C. canariense* pollen prevented large number of pollinations with cultivated chickpea. This could be one of the limiting factors for the success of this cross. Although hybrid plants were not obtained, information is now available on the nature of barriers operating in the cross involving cultivated chickpea and perennial wild species *C. canariense*.

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Anther Culture of Chickpea

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Since the discovery by Guha and Maheshwari (1964, 1967) the immature pollen could be induced to bypass normal development within the anther and the production of haploid plants was first realized in *Datura innoxi.* Since then, haploid plant production has been reported in more than 200 species (Dunwell 1986). Today, androgenetic haploids have been developed in economically important plants such as vegetable crops and cereals

(Villeux 1994, Cao et al. 1995). The production of haploid plants from anther culture technique offers a rapid achievement of homozygous lines for early release of new crop varieties. Besides, it allows the use of haploid cells or protoplasts for the induction and selection of recessive mutants.

In chickpea (*Cicer arietimum*), callus induction and subsequent plant regeneration from cultured anthers have been difficult. The factors affecting induction of androgenesis and organogenesis, pollen embryogenesis, and chromosomal variation in cultured anthers of chickpea have been studied by Khan and Ghosh (1983), Bajaj and Gosal (1987), and Gosal and Bajaj (1988). In the present investigation anthers of five chickpea varieties were used to study their ability for induction of calli and regeneration of pollen plants.

Anther donor plants of five chickpea cultivars Nabin, Deshi (Local), ICCL 83105, ICCL 85222, and Bari Chhola 5 were grown in the field of Institute of Biological Sciences, University of Rajshahi, Rajshahi, Bangladesh during the main crop season (October 1998 to March 1999). Flower buds from primary branches were collected. When the anthers contained pollen at mid to late uninucleate stage (observed by 1:3 acetocarmine staining under the microscope) the flower buds were wrapped in moist tissue paper with aluminium foil and were cold pretreated at 4–5°C for three to seven days. Sterilization of flower buds was carried out by dipping them intact in 70% ethyl alcohol for 1 min just before inoculation of anthers. The outer covering of the bud was removed with a pair of forceps and anthers were separated and placed in 7.5 ml callus induction medium. The callus induction media consisted of MS (Murashige and Skoog 1962), B5 (Gamborg et al. 1968), or N6 (Chu et al. 1975) salts and vitamins fortified with 2,4-dichlorophenoxyacetic acid (2,4-D) alone and 2,4-D or naphthalene acetic acid (NAA) with 6-benzyl aminopurine (BAP) or kinetin (KIN) in 6 cm petri dishes. The pH of the media was adjusted to 5.7 and all the media were solidified with 0.7% Difco bacto agar. On an average 20–30 anthers were inoculated per petri dish. Petri dishes were sealed with parafilm and were incubated at 25±1°C in the dark for callus induction. Anther derived calli subcultured on regeneration medium were exposed to 16 h photoperiod for shoot regeneration. The subcultured calli on regeneration medium were observed in each experiment by counting the frequency of calli formed and the number of shoots per callus. For callus induction and regeneration of shoots MS, B5, and N6 basal media with different auxins and cytokinins were used.

For induction of calli from anthers and their subsequent regeneration, different concentrations of auxins and cytokinins were used. These hormonal concentrations were tested in three basal media, viz., MS, B5, and N6. Callus induction efficiency of anthers greatly varied in the culture media with different hormones. Callus was induced in all media tested but there was much variation in morphological nature and percentage of callus formation. For induction of calli from anthers a combination of auxin and cytokinin was more suitable than auxin alone. Highest (80%) callus formation was observed in media containing B5 + 2 mg L^{-1} NAA + 2 mg L^{-1} BAP in Nabin and B5 + 2 mg L^{-1} NAA + 1 mg L^{-1} BAP in ICCL 83105. Embryogenic responses were observed in media containing BAP with 2,4-D or NAA. Satisfactory amount of globular embryos (5–10) per callus were produced in B5 + 2 mg L^{-1} 2,4-D + 2 mg L^{-1} BAP in Nabin and B5 + 2 mg L^{-1} NAA + 2 mg L^{-1} BAP in ICCL 83105. It was observed that only cream colored calli produced globular embryos. Of the five genotypes tested, Nabin and ICCL 83105 showed high frequency of calli formation and produced globular embryos on the surface of callus.

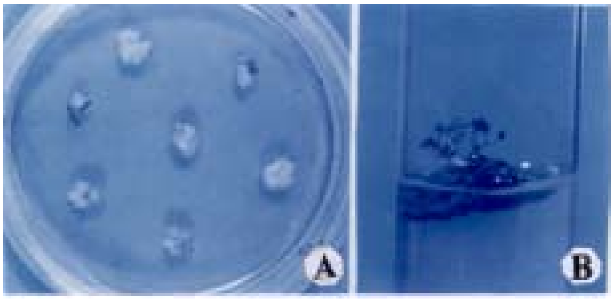

Figure 1. Callus induction and subsequent plant regeneration from anthers of chickpea cultivar ICCL 83105. A. Induction of embryogenic calli from anthers after 6 weeks of culture. B. Shoots produced from anther derived callus after 8 weeks of culture.

For differentiation of shoots, calli induced from anthers of Nabin in B5 + 2 mg L^{-1} 2,4-D + 2 mg L^{-1} BAP and from anthers of ICCL 83105 in B5 + 2 mg L^{-1} NAA + 2 mg L^{-1} BAP were subcultured in MS, B5, and N6 basal media supplemented with different concentrations and combinations of BAP, KIN, and indole acetic acid (IAA). After 8 weeks of culture, 15% of calli from anthers of ICCL 83105 produced shoots in B5 + 1 mg L^{-1} BAP + 0.5 mg L^{-1} KIN + 0.5 mg L^{-1} IAA (Fig. 1). The average number of shoots produced per callus was 2.5. But the calli of the same genotype when subcultured in MS and N6 media failed to initiate shoots. Calli of Nabin failed to differentiate any shoots in any of the basal media used.

Altaf and Ahmed (1986) studied the efficiency of callus induction on anthers of chickpea using different hormonal concentrations. They observed that mature anthers exhibited very little or no response and greenish white anthers having meiotic cells or pollen mitosis showed maximum cellular proliferation. Callus was cream or green in color and became loose and friable after three to four subcultures but no shoot proliferation was observed. Khan and Ghosh (1983) also induced callus from anthers of chickpea but the calli did not produce shoots; however, roots were produced.

Pollen embryogenesis and chromosomal variation in cultured anthers of three Indian genotypes (G 543, L 550, and Hare Chhole) of chickpea were reported by Gosal and Bajaj (1988). Maximum frequency of callusing (61.7%) was observed in Hare Chhole and following transfer to fresh medium 0.52% calli showed somatic embryos. However, the embryos failed to germinate.

In chickpea anther culture, the frequency of callus formation was high, but the efficiency of shoot regeneration from anther derived callus was very low. We must seek ways to improve the cultural conditions and to resolve the problem of regeneration of complete plants from anther derived calli.

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Pigeonpea

Breeding

Characterization and Preliminary Evaluation of Pigeonpea Germplasm in Myanmar

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Genetic improvement of pigeonpea (*Cajanus cajan*) is included as part of the national research program of Myanmar. Myanmar has also established the genetic conservation of orthodox seed with storage facility. In 1998 pigeonpea was included as one of the seven crops planned for multiplication and evaluation by the Seed Bank, Central Agriculture Research Institute, Yezin, Myanmar. Forty pigeonpea accessions were planted for characterization and preliminary evaluation at the Tropical Crops Research Farm, Nyaung-U, Myanmar located between 21°12' N and 94°54.5' E and at 63 m above sea level. Among these, four accessions belong to local collection and the rest were introduced from ICRISAT.

The trial was arranged using randomized complete block design with two replications and three varieties, ICPL 87, ICP 7035, and local 5-seeded pigeonpea were added as checks for short-, medium-, and long-duration respectively. The plot consisted of 0.9×3.7 m rows with inter-row spacing of 60 cm for short-duration accessions and 120 cm for long-duration accessions.

Eight characters, i.e., growth habit, stem color, flower main color, flowering pattern, seed main color, seed color pattern, days to 50% flowering, and days to 75% maturity were scored by block observation whereas plant height, number of pods plant^{-1}, and 100-seed mass were recorded on 3–5 representative plants of each accession. The data were recorded in accordance with the Myanmar Pigeonpea Descriptor developed by the Seed Bank staff and Japan International Cooperative Agency (JICA) experts.

Six qualitative characters were expressed in frequency percentage and grouped into different categories (Table 1). Spreading and semi-spreading plant types were much more dominant than erect and compact type in growth habit. Thirty-three out of 40 accessions had yellow flower color; 3 orange colored and 4 light yellow colored accessions were also found. Twenty accessions (50%) had determinate flowering pattern, while 42.5% were indeterminate types and 7.5% were semi-determinate types. A large portion of the accessions (87.5%) had plain seed color and the rest (12.5%) had mottled seed color pattern. At least 60% of the accessions had brown seed color, 5% each had white and light brown, and the remaining 30% had cream colored seed.

A remarkable amount of genetic variation was observed in five quantitative traits: plant height, days to 50% flowering, days to 75% maturity, no. of pods plant^{-1}, and 100-seed mass (Table 2). The earliest accession was ICPL 85010 with a minimum of 145 days to 75% maturity when compared with the three checks. ICPL 87 (short duration) matured in 174 days, ICP 7035 (medium duration) in 199 days, and the local 5-seeded variety (long duration) in 217 days.

Table 1. Frequency distribution of six qualitative traits in 40 pigeopea germplasm accessions evaluated in Myanmar.

Descriptors	No. of accessions	Frequency (%)
Growth habit		
Erect and compact	4	10.0
Semi-spreading	16	40.0
Spreading	20	50.0
Stem color		
Green	22	55.0
Sun red	18	45.0
Flower color		
Light yellow	4	10.0
Orange	3	7.5
Yellow	33	82.5
Flowering pattern		
Determinate	20	50.0
Semi-determinate	3	7.5
Indeterminate	17	42.5
Seed color pattern		
Plain	35	87.5
Mottled	5	12.5
Seed color		
Brown	24	60.0
Cream	12	30.0
Light brown	2	5.0
White	2	5.0

Table 2. Evaluation of quantitative traits in 40 accessions of pigeonpea germplasm in Myanmar.

Descriptors	Range	Mean	SD	CV (%)
Plant height (cm)	78.3–192.0	133.3	16.6	12.4
Days to 50% flowering	96.0–167.5	125.7	9.7	7.7
Days to 75% maturity	145.5–199.0	168.1	7.0	4.2
No. of pods plant^{-1}	18.2–202.7	62.5	33.9	54.3
100-seed mass (g)	6.5–15.2	9.9	1.3	13.4

The data on 100-seed mass was interesting; the maximum seed mass (15.2 g) was recorded in the early-maturing accession ICPL 83024 (172 days) compared to 16.3 g in the long-duration check, local 5-seeded variety (217 days). However, the largest number of pods plant^{-1} was observed only in late-maturing accessions. Positive correlation between plant height and days to maturity was evident in this study. The evaluated data were documented and revealed for breeders to utilize in the national pigeonpea crop improvement program in Myanmar.

Pigeonpea Germplasm in China

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The landraces of cultivated types and their wild relatives offer a unique gene pool which plays an important role in the genetic improvement of crop plants. Therefore, enrichment of the gene pool should be a continuous process for the long-term benefit of the crop improvement programs. In China, although pigeonpea (*Cajanus cajan*) was introduced about 1500 years ago (Zhuojie 1997), it is not a major crop at present. The landraces of the crop, however, have been preserved and are still grown in various provinces of southern China. These include Yunnan, Guizhou, Hainan, and Guangxi where large extents of pigeonpea were cultivated until 1989 for lac production and fuel wood (Zhenghong et al. 1997). In addition, the crop also spread to some areas in Guangdong, Jiangxi, Sichuan, Fujian, and Hunan provinces. The traditional folk medicinal use of pigeonpea is still practiced by local farmers. In all the nine provinces, pigeonpea is maintained in hilly forests and in the backyard of some farmers. These landraces contain significant variation for different traits but so far there has been no systematic effort to collect, evaluate, and preserve this wealth of germplasm. Considering the importance and danger of losing these genetic materials due to introduction of new crops and clearing of forests, some attempts have been made by local scientists to collect pigeonpea landraces within their own province. This article summarizes the results of such efforts and the current status of pigeonpea germplasm in China.

In Yunnan Province, pigeonpea collection efforts were made by the scientists of the Institute of Insect Resources, Chinese Academy of Forestry, Kunming. The first pigeonpea collection mission was undertaken as early as 1960 in some areas of this province. About 20 landraces were collected, but there is no record of availability of this material at the institute and it was lost over a period of time. The second collection mission was undertaken sometime in 1980s. In this mission 28 landraces were collected and the documentation record of some of their agronomic characters is available. During 1996–98, the third pigeonpea collection mission was undertaken and 76 landraces were collected from 10 counties of Lincang, Cuxiong, Simao, and other prefectures. These germplasm lines contain a significant genetic variability for seed color, seed shape, flower color, and pod color (Table 1). The landraces of Yunnan Province with a life span of 5–10 years have been cultivated for a long time and are similar in maturity. The seed yield is around 35 g plant^{-1}. The variation among the landraces for color of flower, pod, and seed was significant. The flower color was red, yellow, or mixed. The variation in seed color was also large, and included white, cream, gray, dark brown, and variegated.

In Guizhou Province, pigeonpea germplasm was collected in 1987 from the adjoining areas of Guizhou and Guangxi provinces and it represented 10 counties located in the Nanpan river valley. Although the record

Table 1. Summary of pigeonpea germplasm collections in China.

Year	Area	Number of collections	Main characters
1960s	Partial areas in Yunnan	20	Material lost and no documents available.
1980s	Partial areas in Yunnan	28	Seed color: gray, brown, and speckle. Seed shape: round and oval.
1987	10 counties in Guizhou	Unknown	Flower color: red and yellow. Dry pod color: brown, drab, and blackish brown. Seed color: cream, blackish brown, and dark brown. Seed shape: round and oval. 100-seed mass: 8–10 g. Plant height: 3–6 m. Maturity: long duration.
1985–89	13 counties in Hainan	25	Seed color: gray, brown, black, and spot. Seed shape: round, oval, and rectangular. 100-seed mass: 4.5–11.7 g. Maturity: long duration.
1991–95	5 counties in Guangxi	12	Flower color: yellow. Seed color: brown and cream. Seed shape: round and oval. Plant height: 3–4 m. Maturity: long duration.
1996–98	10 counties in Yunnan	76	Flower color: yellow, red, and reddish yellow. Fresh pod color: green, purple, and streak. Seed color: white, cream, gray, brown, black, and speckle. Seed shape: round and oval.

of the genetic variation in the collection is available, the number of collections was not recorded. The material had large variation for important characters such as flower and pod color plant height, maturity, seed size, seed color, and seed shape (Table 1). The plant height in the germplasm varied between 3 m and 6 m, when perennial (1–4 years old) plants were measured. Plants with both red and yellow flower colors were found. The mature pod colors observed were brown, yellowish brown, and dark brown. The seed color of the material was cream, brown, or dark brown. The 100-seed mass was 8–10 g. Analysis of nutritional contents of whole seed samples showed that the protein content was 16–19%, lipid content was 1.5%, and starch content was 38.8–45.6%. The local landraces were commonly distributed in the river valley from the elevation of 380 m to 700 m. Most of the landraces were found growing in the hills and forests (Feijie et al. 1991, Julian and Xunsheng 1991).

In Hainan Province, 25 pigeonpea landraces were collected during a national crop germplasm collection mission in 13 counties. The collections were classified into two groups: yellow-flowered pigeonpea and double color-flowered pigeonpea. Most of the yellow-flowered pigeonpeas were short statured and early in maturity; the dorsal and ventral surfaces of the flowers were yellow. Matured pods were small, yellow-brown in color having 2–3 seeds. The seed color was cream with dark speckles. Most perennial pigeonpea landraces had mixed flower color. This group was characterized by high vigor, large plant size, late maturity, and yellow flower color with red stripes. The pods were brown or dark brown when mature, with 4–5 seeds per pod. The plant height was 1.5–3.5 m. The seeds were round or oval and black or light gray. Pigeonpea landraces in Hainan Province were found in marginal lands or in backyard gardens. Seed damage by insects was usually high.

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Performance of ICRISAT Pigeonpeas in China

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Introduction of pigeonpea (*Cajanus cajan*) materials from ICRISAT, Patancheru, India into China began in 1985 when a Pigeonpea Observation Nursery (PON) was grown at Guangzhou. This nursery consisted of a range of materials and its major objective was to obtain primary information about some basic adaptation parameters such as maturity and plant type. This information helps in decision-making in introducing more germplasm within the adapted plant types and maturity groups for more refined evaluation and selection. The PON, sown at the onset of the rainy season on 9 March revealed that the short-duration pigeonpeas were relatively better adapted than medium- and long-duration types. Yield of the short-duration lines was 1.0–1.2 t ha^{-1} while that of the medium-duration types was 0.3–0.9 t ha^{-1}. The local control (Fongsoon) flowered in 180 days and produced 0.65 t ha^{-1} yield. ICRISAT's long-duration lines were found to be extremely photoperiod sensitive and took more than 200 days to flower; they failed to produce grains.

As a follow-up, a set of 16 short-duration determinate lines were evaluated in 1988 in a replicated trial at Guangzhou. The trial was sown on 27 April at spacing of 65 × 33 cm. The 50% flowering in the test lines ranged between 54 days and 86 days. ICPLs 85033 recorded the highest seed yield of 2.03 t ha^{-1}, followed by ICPLs 86010, 86005, 87, 84037, and 83024 (Table 1). The local check took 115 days to flower and produced significantly low yield (0.37 t ha^{-1}).

In spite of demonstrating high yield potential and good adaptability in Guangzhou, the follow-up research and development activities on short-duration pigeonpeas could not be continued due to various unavoidable reasons. After a gap of 10 years the interest in ICRISAT's pigeonpea was revived but this time it was in Guangxi and Yunnan provinces. At the Guangxi Academy of Agricultural Sciences, Nanning in Guangxi Province the main research emphasis was on fodder production, grazing, and soil conservation while at the Institute of Insect Resources, Chinese Academy of Forestry, Kunming the prime aim was to exploit the potential of pigeonpea for soil conservation.

In 1998, 18 advanced pigeonpea breeding lines were evaluated in rainy season at Nanning in Guangxi province. The unreplicated trial was sown on 22 April in four-row plots. The spacing between and within rows was kept at 100 cm and 50 cm respectively. ICPL 90011 did not germinate. Data on various plant and seed characters were recorded on plot basis. Based on maturity the genotypes were classified into three groups: short duration (130 days), medium duration (180–250 days), and long duration (>250 days). In general short- and medium-duration lines were compact, short in height, and uniform in flowering and podding. The long-duration types were tall and spreading. All the lines were susceptible to *Helicoverpa* and *Maruca* pod borers and blister beetles. The local check was very late and spreading and produced a lot of biomass but low seed yield. Based on their performance ICPLs 90008, 93012, 93047, 93081, 93092, 87091, 87119, and ICP 7035 were selected for further testing.

Evaluation for Biomass Production

In parts of southern China, characterized by high rainfall of about 1000 mm, pod borer damage to pigeonpea is extensive due to high temperature and high humidity. Even 3–4 sprays of Chloropyriphos 20 EC at 300 ml ha^{-1} are not effective. In such areas, however, pigeonpea not only

Figure 1. Seed production of ICRISAT pigeonpea line ICPL 87091 in Guangxi province, China.

Figure 2. A short-duration pigeonpea variety intercropped with soybean in Guangxi province, China.

Table 1. Performance of short-duration determinate ICRISAT pigeonpea lines tested in Guangzhou, China during 1988.

Entry	Days to flower	Plant height (cm)	100-seed mass (g)	Grain yield (t ha^{-1})
ICPL 85033	75	143	10.5	2.03
ICPL 86010	73	152	10.3	1.98
ICPL 86005	73	130	11.2	1.95
ICPL 87	75	147	9.6	1.81
ICPL 84037	74	140	10.5	1.80
ICPL 83024	81	158	12.5	1.79
ICPL 85021	86	139	10.7	1.54
ICPL 83009	73	136	8.6	1.48
ICPL 87046	83	166	10.6	1.47
ICPL 151	73	134	8.4	1.46
ICPL 86003	65	116	8.7	1.37
ICPL 86012	73	136	9.4	1.23
ICPL 85016	73	130	5.6	0.95
ICPL 83004	54	107	6.4	0.82
ICPL 87047	80	157	7.9	0.73
ICPL 4	73	132	4.4	0.73
Local check	115	213	7.8	0.37
SE ±	0.6	6.8	0.64	0.17
CV (%)	1.5	8.2	12.32	21.6

grows at a faster rate but also produces large biomass of fresh leaves and tender branches. Hence, pigeonpea can be used as a fodder and pasture crop for goat and buffalo. In 1999 cropping season short- and medium-duration pigeonpea lines and a local check were evaluated for biomass production in Nanning in unreplicated plots. Sowing was done on 20 April. Inter-row spacing was 100 cm while plants within the row were spaced at 40 cm. ICPL 88009 was the earliest (100 days to flower). The local check took about 8 months to flower. ICPL 85010, ICPL 93047, ICPL 87119, ICP 7035, and local check produced more than 50 t ha^{-1} fresh biomass and about 25–30 t ha^{-1} of dry biomass. The data also indicated that in comparison to local check, ICRISAT lines were more efficient in dry and fresh mass accumulation rates. The promising lines from this material will be selected for more detailed studies in agronomy, feeding, and multiple cutting trials in the next season.

During 1999 cropping season, two ICRISAT pigeonpea lines ICPL 90008 and ICPL 87091 were evaluated for fodder and seed yield in Duan county in Guangxi Province (Figs. 1 and 2). The plantings were done at two locations, one representing high mountain slope and another flat lowland. These lines were sown at the beginning of rainy season on 20 April and towards the end of rainy season on 10 July. The lines took more time to flower and the plants were more vigorous in early sown (April) than late sown (July) crops. In lowland, ICPL 87091 took more time to flower and mature and produced more biomass than ICPL 90008.

Soil Conservation

The Institute of Insect Resources of the Chinese Academy of Forestry, Kunming tested a number of ICRISAT germplasm lines for soil conservation in Yunnan Province. From these, six lines were identified for large-scale field evaluation in agroforestry, intercropping, and coverage of slopy lands.

The newly developed ICRISAT pigeonpea lines have shown great promise for monocropping and intercropping systems in China. At present Guangxi and Yunnan provincial governments have developed elaborate plans to multiply seed of the promising lines and conduct a series of on-farm trials in the counties where high levels of soil erosion and drought do not permit the cultivation of other food legumes economically.

Wild Relatives of Pigeonpea in China

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Wild relatives play an important role in the genetic improvement of cultivated crops. Breeders turn their attention to the wild relatives of crops after unsuccessful search for some unique trait in the cultivated germplasm. According to van der Maesen (1986) the genus *Cajanus* has 32 species. Of these, the Indian subcontinent harbors 18 species. ICRISAT has the global responsibility of collection, maintenance, and evaluation of germplasm of the wild relatives of pigeonpea. At present a total of 213 accessions, representing 20 *Cajanus* species are conserved for use in the breeding programs.

China is known for maintaining high level of biodiversity of different crop species. But the collection and evaluation of pigeonpea and its wild relatives has been rather limited. In ICRISAT's global germplasm collection of wild species none is of Chinese origin. van der Maesen (1986), while reviewing the taxa that are closely related to pigeonpea, listed six species which were found earlier by various researchers in China. The detailed description of these species with respect to their distribution and morphology is given by van der Maesen (1986) in his monograph. For quick reference a brief description of these species is given below and the key for indentification is given in Table 1.

Cajanus crassus (Prain ex King) van der Maesen

Cajanus crassus is distributed in India, Myanmar, Thailand, China, Vietnam, Philippines, Java, and Malaysia peninsula. In Myanmar, it is locally called Pe yaing or Taw pe. In China it has been reported to be found in Yunnan Province in Manhao prefecture, Tonkinensis, Manpau, Red River Valley, middle part of E Mount Poo Peng, and on Babien-Ho between Talang and Puorl.

Cajanus crassus is a perennial climber. Leaves are dark, pinnately trifoliate, and lower surface of the leaflets is pubescent. Racemes are crowded and corolla yellow. Calyx is pubescent with short hairs. Pods are sturdy and oblong (2.5–5 cm in length) and contain 5–6 rectangular, rounded, black or cream colored seeds.

Cajanus goensis Dalz.

Besides China, *C. goensis* is found in a number of Asian countries. In China it is reported to occur in Yunnan Province. The areas where this species has been located are Szemao mountain, Yu Lu mountain, Haba Snow Range and between Manua and Mantung near Teshelo/ Kenghun on Mekong River. It is generally found at 1000–1300 m altitude and flowers in September. In Myanmar it is called Ioe htun. According to Rama Rao (1914), *C. geonsis* is a good herbal medicine. A decoction of root powder is suitable for curing rheumatism, biliousness, impurity of blood, fever, heat, and swelling. It also improves vitality, increases phlegm, and constipates bowels.

It is a perennial climber with long sticky, brown hairs on almost the entire plant. Leaves are pinnately trifoliate with long petioles. Leaflets have prominent ribs. Racemes are lax and pubescent. Pods are curved or straight, narrowed to both ends, and covered with long hairs. Seeds are broad and light brown in color with black mosaic.

Cajanus grandiflorus (Benth. ex Bak.) van der Maesen comb. nov.

In Chinese language *C. grandiflorus* is called Siao Cho Ten or Siau Ko Ten. Besides China, *C. grandiflorus* is also found in India and Bhutan. In China it is reported to be found in several areas of Yunnan, Kweichow, and Anhwei provinces. In Yunnan province *C. grandiflorus* is present in Hinyu-hien, La Long Tan, Teng Chung, west bank of Shweli-Salween divide, and Mount Mangtze. *Cajanus grandiflorus* is a climber with branches covered with hairs. Leaves are pinnately trifoliate with membranous leaflets. Racemes are lax with yellow flowers. Pods are 3.5–5 cm long and covered with hairs. Seeds are round and compressed.

Table 1. Key to wild *Cajanus* species reported in China.

A.	Erect shrubs.	
	Leaflets rounded-obovate, whitish below, pods 4–6 seeded.	- *C. niveus*
AA.	Climbing or creeping plants.	
	B. Leaflets small.	
	Leaflets elliptic or obovate-obtuse, twiner in grasses.	- *C. scarabaeoides*
	BB. Leaflets large.	
	C. Flowers large.	
	Corolla persistent calyx with bulbous based hairs.	- *C. grandiflorus*
	CC. Flowers small.	
	D. Corolla not persistent.	
	Indumentum fine, spreading, green, bracts very hairy.	- *C. goensis*
	DD. Corolla persistent.	
	E. Leaflets semi-coriaceous.	
	Leaflets densely gray, hairy below, end leaflets longer than broad, pods 8–10 seeded.	- *C. mollis*
	EE. Leaflets coriaceous.	
	Leaflets brown, pubescent below, end leaflets broader than long, pods 3–5 seeded.	- *C. crassus*

Figure 1. *Cajanus scardabaeoides*, a wild relative of pigeonpea found in bushes of Guangxi province in China.

Cajanus mollis (Benth.) van der Maesen comb. nov.

Cajanus mollis is distributed in various countries located in the Himalayan foothills. In China, it has been reported is Szemao mountain, Mapan and Red River Valley in Yunnan Province. It is a perennial climber with very long branches. Leaves are trifoliolate with soft leaflets and prominent ribs. Racemes are short and crowded. Pods are sturdy and oblong ends rounded, 3.5–4.5 cm long and densely puberulous. Seeds are ellipsoid to rectangular in shape and whitish in color.

Cajanus niveus (Benth.) van der Maesen comb. nov.

Cajanus niveus has been reported from several locations in Myanmar and Yuenkiang and Ue mountain of Yunnan Province in China. This species is an erect perennial shrub with green pubescent grayish branches. Leaves are pinnately trifoliate; leaflets are covered with dense pubescence and have prominent ribs. Racemes are short. Pods are oblong, obtuse at both ends, and covered with hairs. Seeds are cylindrical with very large strophiole.

Cajanus scarabaeoides (L.) Thouars

Cajanus scarabaeoides is widespread in Asia. In China, it is called Shui Kom Ts'o and found at altitudes from sea level to 1000 m. In Yunnan Province it is endemic in Yang Tse Ferry near La Ka Triang between Yunnansu and Huili while in Hainan it has been found growing in Wanning. It is useful in pastures (Dabadghao and Shankarnarayan 1973). Kirtikar and Basu (1933) reported that *C. scarabaeoides* is effective against diarrhea in cattle. In August 1999, the authors found this species growing in the wastelands at 180 m elevation in Tiandong County of Guangxi Province in China (Fig. 1). At this location, plants of different ages ranging from young seedlings to perennials were found. Some plants were in podding stage.

In addition to the six species described, a new species was observed in 1999. The authors while monitoring pigeonpea trials in Guangxi province located a few plants (3–4 years old) of a wild relative of pigeonpea growing in the backyard of a farmer in Fengshan County of Guangxi province at 810 m altitude. In August the plants were at early flowering stage. According to the farmer the plants of this species were grown as a hedge crop around his house for several years but only few survived grazing. Based on the perennial habit, general morphology, leaf shape, and open branching habit, this species was suspected to be *C. cajanifolius*, the putative progenitor of pigeonpea. However, the critical seed characteristics, such as seed color and presence of strophiole could not be examined as the plants were in early flowering stage. It is important to revisit this location to confirm that the species is *C. cajanifolius*.

Among the wild species so far reported to occur in China, only *C. scarabaeoides* can be crossed freely with pigeonpea. It is, therefore, suggested that the samples of these species be collected and evaluated in China for various economic traits for use in the breeding program, if necessary.

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China-ICRISAT Collaboration on Pigeonpea Research and Development

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Collaboration between ICRISAT and China on pigeonpea (*Cajanus cajan*) research started in 1997 when 18 advanced breeding lines were introduced from ICRISAT by the Institute of Crop Germplasm Resources (ICGR) of the Chinese Academy of Agricultural Sciences (CAAS) for evaluation in Nanning (Guangxi Province), Ganzhou (Jiangxi Province), and Haikou (Hainan Province) in China. In Nanning and Ganzhou, the crop performed well with seed yield of 1–2 t ha^{-1} while in Hainan Island it failed due to severe insect damage. In this province the local pigeonpea, characterized by very late maturity and small unacceptable seed size, is still grown by farmers for soil conservation and as a hedge crop. Since ICRISAT lines were found unadapted in Hainan, the testing program was continued only in Guangxi and Jiangxi provinces. In 1998, we also started pigeonpea research in southern hills of Yunnan province.

During 1998 and 1999, we not only identified superior varieties but also developed the concept of utilizing pigeonpea for fodder and soil conservation in the dry areas of these provinces. In these areas, soil erosion is a very serious issue and the establishment of forest trees for soil protection takes a long time (5–10 years). Pigeonpea, on the other hand, starts protecting soil within a year and in addition it provides food also. Since in these mountainous provinces agriculture is very difficult, the government is promoting animal husbandry, especially goats and cattle. The availability of quality fodder for the animals is the main cause of concern in the promotion of animal husbandry. During the trials conducted in 1998 and 1999, we observed that pigeonpea can be used for soil conservation. It also has a great potential as a fodder crop in the rainfed dry hills. Therefore, our research and development activities concentrate around soil conservation and fodder production. In addition, pigeonpea provides much needed fuel wood. We are also aiming to use pigeonpea for fresh vegetable production in certain niches such as Beijing and Jiang Su province where the growing season is short and insect problems are not so serious.

Present Status

During 2000, we considerably extended pigeonpea promotion activities in Yunnan (2000 ha), Guangxi (670 ha), and Jiangxi (500 ha) provinces with a seed backup program in each province. The new materials introduced this year from ICRISAT are being evaluated to find out new high-yielding, widely adapted varieties. These include a number of breeding lines and germplasm. ICPL 87119, ICP 7035, ICPL 87091, and ICPL 89008 are promising. The recent breeding lines capable of producing high quality fodder also appear to hold high promise for fodder and grazing. At the Buffalo Research Institute of CAAS (in Nanning), for the first time a large-scale pigeonpea production program was undertaken during 2000. Besides conducting research on fodder production and its nutritional efficiency, 20 ha of pigeonpea was planted for seed production. Special efforts will be made to multiply breeders' seed. The ability of pigeonpea plant to grow under rocky mountain areas without fertilizer, irrigation, or pesticide has impressed the scientists in China. We are also evaluating local germplasm and crosses are being made to develop our own pigeonpea breeding program.

In Beijing, the season for a crop like pigeonpea is short due to prevailing low temperatures. During 2000 evaluation of 42 pigeonpea lines was undertaken to identify germplasm which could provide fresh vegetable. Also from this experiment we plan to identify genotypes which will survive the sub-zero temperature and regenerate in the next spring. For vegetable purpose and seed production, ICPL 151, MN 1, MN 8, ICPL 85010, and ICPL 87091 have shown good results. In Guizhou province, ICPL 87091 and ICPL 87119 are being evaluated for fodder production. The crop at present is excellent and it will be utilized for seed production.

The Constraints

Since pigeonpea is a new crop, the major constraints are untrained human resources, both at research and extension works. Among diseases, only phoma stem canker has been found in almost all the pigeonpea-growing areas. Quality seed production is another important constraint as seed damage by insects is common. We need new genetic materials from ICRISAT which have resistance to phoma stem canker, and produce high fodder and seed yield.

ICRISAT Support

The support received from ICRISAT in conducting pigeonpea program in China has been very valuable to us and we are proud of it. During the last three years ICRISAT has provided new breeding lines and germplasm which is the backbone of our program. ICRISAT has also been providing the services of their scientists on a regular basis. We, in particular, acknowledge the scientific input of Dr K B Saxena, ICRISAT whose sincere efforts, interest, and enthusiasm in promoting pigeonpea in China has helped our research and development program immensely. China Central Radio Station (CCRS) and China Central Television Station (CCTV-2) have prepared special programs on pigeonpea. In collaboration with ICRISAT a booklet "Handbook of Pigeonpea in China" coauthored by Zong Xuxiao, Li Zhenghong, Yang Shiying, Zhou Chaohong, and K B Saxena will soon be published in Chinese. This booklet will help us in promoting pigeonpea in the country.

A training program was organized by ICRISAT for four Chinese scientists for two months (1 Dec 1999 to 1 Feb 2000). The program helped the scientists in understanding more about the prospects and problems of the crop. They were provided an opportunity to select breeding materials and germplasm from ICRISAT fields. Recently, ICRISAT provided 1000 kg seed of ICPL 87119 which will be utilized for multiplying pure seed stock for future use. Our links with ICRISAT have helped us in developing our own scientific base on pigeonpea.

We hope in future ICRISAT will not only continue to support us but also increase its input to strengthen our program. This support will help the poor farmer in mountain areas of southwest and southern parts of China, and will enrich the food spectrum in China.

Program for 2001

- Pigeonpea area in Guangxi, Jiangxi, Yunnan, and Guizhou provinces will be increased to about 6000 ha.
- Three pigeonpea varieties will be officially registered and released for production.
- Research on the utilization and production of fodder pigeonpea will be continued.
- Screening of new germplasm will be continued.
- Large-scale vegetable production program will be undertaken in Beijing.
- In Guizhou province, about 75 ha of pigeonpea will be planted for seed production and grazing.
- Screening for phoma stem canker resistance will be done.
- Intercropping of pigeonpea with maize (*Zea mays*) and other crops will be studied.
- Testing of new pigeonpea lines in Hainan island will be done.
- Seed of dwarf pigeonpea will be multiplied.
- It is proposed to organize an in-country meeting of all pigeonpea and chickpea workers to review the program, identify constraints, and develop plans for the coming years.
- A booklet on pigeonpea production and utilization will be printed.
- Links with private sector will be available to support the seed program.

Conclusions

The new initiatives of promoting pigeonpea in China have been very successful. We have demonstrated its utility in soil conservation, fodder, feed, fuel, food, and vegetable production. In the last three years, a significant progress has been made in identifying varieties, constraints, and production areas. The support provided by ICRISAT is invaluable to us. We hope ICRISAT will continue to strengthen our program to meet our obligations of helping poor farmers of southern China, and protecting the poor slopy lands for sustainable agriculture in China while providing useful products and enriching the food spectrum for the Chinese population.

Evaluation of Short-, Medium-, and Long-duration ICRISAT Pigeonpea Cultivars in Mpumalanga, South Africa

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Pigeonpea (*Cajanus cajan*) is not grown widely as a field crop in South Africa. A few stands of long-duration, unimproved pigeonpeas are usually grown singly or as a hedge plant in home gardens or around sugarcane (*Saccharum officinarum*) fields in several provinces such as Kwazulu-Natal, Mpumalanga, and Northern and Eastern Cape Provinces in South Africa. The green peas are used as vegetable and the dry whole seeds for making soup mixed with or without meat.

Pigeonpea has a crucial role in sustaining agriculture in rainfed and semi-arid farming systems. Therefore, studies were initiated during 1998/99, to evaluate the performance of improved pigeonpea cultivars developed by ICRISAT in India and Kenya, under rainfed conditions in Mpumalanga Province for possible inclusion in the dryland farming systems in Lowveld.

Sixteen cultivars with varying maturity periods were evaluated in two separate trials, one with 8 short-duration (SD) cultivars and the second one with 5 medium-duration (MD) and 3 long-duration (LD) cultivars in randomized complete block design with 4 replications. The trials were located at Malekutu (25°12′ S 31°12′ E and 350 m above sea level) in Nsikazi District of Mpumalanga Province. The soils are predominantly sandy loams with a pH of 4.2. No fertilizers were applied to the trial plots. Both the trials were planted during the middle of December, and grown under rainfed conditions. A total of 576 mm of rain was received during the cropping season from planting to harvesting of the pigeonpea trials. The growing period temperatures varied from 17.8°C to 28.2°C. The plot size was 3 rows of 6.3 m long spaced at 90 cm in the MD and LD trial and 50 cm in the SD trial. The seeds were sown 10 cm apart in the SD trial. Two plants at each station at 70 cm apart were retained within rows after thinning in the MD and LD trial. Three sprayings with Karate® (cyhalothrin) were carried out in the SD trial plots and one spraying in the MD and LD trial. The data were analyzed using the MSTAT-C program.

In the MD and LD trial, the cultivar ICP 8863 was the earliest to reach 50% flowering by 115 days after planting (DAP) followed by ICPL 87119. None of the LD cultivars had started to flower by that time. The plant height at flowering was significantly lower in ICP 8863 than all the other cultivars evaluated (Table 1). Harvesting of the main crop was completed 193 DAP in

Table 1. Performance of ICRISAT medium- and long-duration pigeonpea cultivars in Mpumalanga, South Africa, 1998/99.

Cultivar	Crop duration	Plant height at flowering (cm)	Plants flowered[1] (%)	Days to maturity	Grain yield (kg ha^{-1})	100-seed mass (g)
ICPL 87051	Medium	180	25.72	193	978	14.8
ICPL 87119	Medium	162	44.46	193	966	12.3
ICEAP 00068	Medium	200	4.40	193	951	16.8
ICP 6927	Medium	205	40.16	193	802	17.3
ICP 8863	Medium	145	69.98	193	709	11.0
ICEAP 00053	Long	225	0.0	231	918	15.8
ICEAP 00040	Long	207	0.0	231	866	19.5
ICEAP 00020	Long	238	0.0	231	736	19.5
Mean		195	23.09		866	15.8
CV%		8.89	53.48		21.74	4.95
LSD (P = 0.05)		25.54	18.16		NS[2]	1.15

1. At 115 days after planting.
2. NS = Not significant.

Table 2. Performance of ICRISAT short-duration pigeonpea cultivars in Mpumalanga, South Africa, 1998/99.

Cultivar	Days to 50% flowering	Days to maturity	Grain yield (kg ha^{-1})	100-seed mass (g)
ICPL 88039	67	127	1823	10.0
ICPL 85010	68	129	1525	9.0
ICPL 87	80	133	1429	11.0
ICPL 84031	77	128	1411	10.3
ICPL 87091	84	140	1299	12.3
MN 5	64	130	1228	8.3
ICPL 87105	83	133	1212	12.3
ICPL 151	76	130	1149	12.3
Mean	74.75	131	1384	10.7
CV (%)	3.99	2.76	31.61	3.64
LSD (*P* = 0.05)	4.39	5.31	NS[1]	0.57

1. NS = Not significant.

MD cultivars and 231 DAP in LD cultivars. No significant yield differences between the cultivars were observed (Table 1). The cultivar ICPL 87051 (MD) recorded the highest grain yield of 978 kg ha^{-1} followed by the MD cultivars ICPL 87119 and ICEAP 00068. Among the LD cultivars, ICEAP 00053 gave the highest grain yield of 918 kg ha^{-1} followed by ICEAP 00040. The average grain yield of the LD cultivars was lower than the MD lines. The planting of the rainfed summer crops in this region normally commence with the advent of the rainy season in October. The overall yield was low, probably due to late planting in December. Pigeonpea grain production is directly associated with biomass production (Chauhan et al. 1995). Being photo- and thermo-sensitive, the MD and LD cultivars produce more biomass when planted early. The MD cultivars ICP 8863 and ICPL 87119 recorded significantly lower seed size compared to all other cultivars. All the plants were cut to a height of 40 cm after the final round of harvest, in September, for ratooning.

In the trial with SD cultivars, the cultivar MN 5 was the earliest and achieved 50% flowering in 64 DAP while ICP 87091 took 84 days. Picking was completed in 127 DAP in the cultivar ICPL 88039 and 140 days in the cultivar ICPL 87091. The cultivar ICPL 88039 gave the highest yield of 1823 kg ha^{-1} but differences between cultivars were not large enough to be statistically significant (Table 2). The cultivar MN 5 had a significantly lower seed size than all the other cultivars.

The preliminary results clearly showed the possibility of successfully growing pigeonpea in the Lowveld areas of Mpumalanga to increase profitability of local farming systems. Preliminary investigations showed that about 120–150 tons of "oil-dhal" is imported from Malawi each month at R 600,000 (US$ 75,000) to R 750,000 (US$ 94,000) to meet the ever-growing demand for dhal by the large Asian community in South Africa. Substantial amounts of foreign exchange could be saved if pigeonpea production is successfully introduced in South Africa. Exporting the grains to countries where periods of short supply occur can also generate additional income. However, there is an urgent need to popularize the crop, develop sustainable production practices, provide adequate training to farmers especially on value addition by processing, and organize efficient markets before commercialization of pigeonpea could commence.

To begin popularizing the crop, a pigeonpea interest group of farmers and extension officials was formed in Nsikazi District in May 1999. The group, during a field visit to the trial with MD and LD cultivars, showed their preference for ICEAP 00040 and ICEAP 00053 based on visual observations on the growth habit of plants and pods. The small seeded ICPL 87119 was the least popular. At a later meeting, the group tasted five local preparations made from the dry whole seeds. Over 80% of the participants considered the taste of pigeonpea as similar to that of beans (*Phaseolus* spp) and cowpea (*Vigna unguiculata*). Twenty per cent preferred its taste and none disliked it.

The trials will be repeated in the coming season before conclusions could be made. A few volunteer farmers will be given selected cultivars to grow in their own gardens in the coming season as part of popularizing the crop among the local population.

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Pathology

Pigeonpea Diseases in China

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Although at present pigeonpea (*Cajanus cajan*) is not a major crop of China, it occupied an important place in rainfed agriculture of southern provinces between 1950 and 1989 mainly for lac cultivation. Pigeonpea cultivation witnessed a significant decline due to the loss of international lac market. Now the crop is receiving renewed interest in Yunnan and Guangxi provinces of China for purposes of soil conservation, fodder, and feed. During this period of the adoption of pigeonpea several plant diseases have occurred in different areas. An account of the prevalent diseases will be useful in the recent effort of popularizing pigeonpea in the country.

According to the Disease-Insect Research Group of Lac Research Institute (DIGRIRI), Chinese Academy of Forestry, nine pigeonpea diseases are prevalent in Yunnan, Guangdong, Hainan, and Guangxi provinces of China. But Shaoji (1985a) stated that in the above report the infections due to fusarium wilt caused by the variants of *Fusarium udum* were regarded as two different diseases. Also, Fuhai et al. (1985) reported that the fungus *Cladosporium* sp in fact attacks the lac insect (*Kerria lacca* Kerr.) and not pigeonpea. Thus there are only seven pigeonpea diseases prevalent in China. A brief description of these is given below.

Fusarium Wilt

Wilt caused by *F. udum* is the most important and widespread disease in lac-producing regions of China (Shaoji 1985a). The major symptoms appear as patches or a dark purple band extending upward from the base on the main stem, and blackening of xylem resulting in partial or complete wilting of the plant. In comparison to one-year-old plants, the two-year-old plants show more susceptibility to infection (DIGRIRI 1978). A survey conducted by DIGRIRI in 1978 showed 15–90% wilt incidence in Jingdon. It was also reported that the plants on which the lac insects were reared or which were excessively exposed to the insect, exhibited relatively more wilt incidence than those plants which did not have the lac insects.

Phytophthora Blight

Plants infected with phytophthora blight, caused by *Phytophthora drechsleri* f. sp *cajani* showed water-soaked lesions on leaves, and brown to dark, or grayish white and sunken-shaped lesions on stems and petioles. The base of the main stem and branches, especially pruned branches were more susceptible to this disease. Under conditions favorable to the pathogen, it causes severe damage. The disease prevails in almost all the lac-growing regions in China, but the losses due to phytophthora blight are more in hot, arid areas. Infection usually sets in only at the beginning of the rainy season and develops rapidly in hot weather. Phytophthora blight was found to be severe in Daolie forest land of Hainan island (DIGRIRI 1978).

Powdery Mildew

Powdery mildew (*Oidiopsis taurica*) is an important disease of pigeonpea in China (Shaoji 1985b). It occurs throughout the year, but is more severe during the rainy season. In Jingdong, generally two peaks are observed one from late February to early May and another from early October to late December (Shaoji 1985b). In Xichang and Sichuan the disease is prevalent from April to June (Xinqiao 1976). The initial symptoms develop as small yellowish white spots on the leaf surface, followed by white powdery patches, and finally blackening of the surface. The disease causes shortening of top young branches, upward clustering of young leaves, and stunted growth of plants. Flowers and pods are also infected and result in the reduction in pod set. Seedlings are susceptible to powdery mildew if exposed alternatively to drought and humidity.

Sterility Mosaic

Sterility mosaic infected plants do not flower and pod. The disease causes stunted plant growth. The initial symptoms are vein-clearing in the younger leaves and in

Table 1. Suggested measures for controlling pigeonpea diseases in China.

Measures	Details	Diseases
Cultural practices	- Use adequate plant ash, and small quantity of manure or superphosphate as base fertilizer.	All diseases
	- Maintain appropriate spacing while seeding and thinning.	
	- Follow crop rotation and intercropping.	
	- Prepare ridges and furrows to prevent waterlogging.	
	- Burn plant debris every year.	
	- After each pruning, spray or smear the cut with 1% Bordeaux mixture.	
Host plant resistance	- Introduce cultivars resistant to diseases or select seed from healthy plants in local sick-fields.	
Chemical control	- At initial infection stage, spray and smear lesion with 0.5% mixture of lime and sulfur or sublimate @ 0.1–0.2%.	Phytophthora blight
	- Seed dressing with 1:1 mixture of 0.3% Seris and 6% Benzex.	Fusarium wilt; also prevents seedling damping off and other soil pests
	- At initial infection stage, spray wettable or dusty sulfur 1–2 times; spray mixture of lime + sulfur @ 3–5%; or spray thiophanate @ 0.1%.	Powder mildew and cercospora leaf spot

localized areas on the leaves of older plants. After October, some plants were found to recover to some extent. The disease is frequently accompanied with powdery mildew. The older plantations exhibit high degree of sterility mosaic and powdery mildew (DIGRIRI 1978).

Cercospora Leaf Spot

Lesions of *Cercospora* spp appear as circular or small irregular brown spots on leaves. Cercospora leaf spot may cause defoliation under severe pressure. Plants infected with *Cercospora* are more prone to attack by other pathogens. The disease is common and its incidence is high, particularly during rainy season (DIGRIRI 1978).

Rust

Rust is caused by *Uredo cajani*. Typical dark brown pustules are present on the lower surface of leaves of the infected plants, giving an appearance of yellowish brown spots. The disease is prevalent only in some areas of China (DIGRIRI 1978).

Phoma Stem Canker

Phoma stem canker is caused by *Phoma cajani* and is observed in Jingdong. It generally occurs in adult plants and is characterized by the appearance of brown, cankerous lesions on the stem. The lesioned portions often develop swellings in old and perennial plants. This disease assumes importance in China in view of the future adoption of pigeonpea as a short perennial crop for soil conservation.

Control Measures

The control measures used in China are based on the theory of improving plant health to build up its resistance. Major disease control measures reported in Chinese literature by DIGRIRI (1978), Shaoji (1985a, 1985b), and Xinqiao (1976) are summarized in Table 1.

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Reaction of Pigeonpea Accessions to Root-knot Nematode *Meloidogyne incognita* and Reniform Nematode *Rotylenchulus reniformis*

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Pigeonpea (*Cajanus cajan*) is a widely grown pulse crop in India and is an important source of vegetable protein. The woody stem residues have great potential as a substitute to the ever increasing demand for solid fuel. The combustibility or energy output from woody plant wastes of pigeonpea depends on its bulk density (Jain et al. 1986). The root-knot nematode *Meloidogyne incognita* (Kofoid and White) Chitwood and reinform nematode, *Rotylenchulus reniformis* Linford and Oliveira have been found consistently associated with plant damage, and reduced biomass and grain yields of pigeonpea. Resistant varieties have been suggested for crop protection

Table 1. Reaction of pigeonpea accessions to root-knot nematode *Meloidogyne incognita* and reniform nematode *Rotylenchulus reniformis*.

Reaction	*Meloidogyne incognita*	*Rotylenchulus reniformis*
Resistant	KA-3	KM-137
Moderately resistant	KM-137, KM-138	KM-138
Susceptible	Pusa(B)25, Pusa(B)27, Pusa(B)34, Pusa-988, P-981, P-982, P-986, MAL-8, MAL-9, MAL-10, MAL-11	KA-3, MA-3, MA-4, MA-6, MA-7, MTH-9611, MTH-9613, MTH-115, P-981, P-982, P-986, Pusa(B)27, Pusa(B)34, Pusa(B)25, Pusa-988
Highly susceptible	AF-345, AF-2039, AL-1340, AL-1381, DPA-92, H-88-22, H-88-25, H-91-23, IPA-95-1, KF-108, KSMR-8, MA-3, MA-4, MA-6, MA-7, MTH-9611, MTH-9613, MTH-115, TAT-9802, TAT-9803, WRG-14, WRGE-11, WRGE-1178	AF-345, AF-2039, AL-1381, AL-1340, DPA-92, H-88-22, H-88-25, H-91-23, KF-108, KSMR-8, MAL-8, MAL-9, MAL-10, MAL-11, IPA-95-1, TAT-9802, TAT-9803, WRG-14, WRGE-11, WRGE-1178

against this nematode. This investigation was undertaken to screen 37 pigeonpea accessions received from the Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India against *M. incognita* and *R. reniformis* to identify possible sources of resistance.

Three to four seeds of each accession were inoculated with *Rhizobium* using 5% sucrose solution as a sticker and were sown in 15-cm diameter clay pots each containing 1 kg steam sterilized soil. After germination, plants were thinned to one per pot. Three-week-old plants were inoculated with 5,000 nematodes plant^{-1} of freshly hatched second stage juveniles (J2) of *M. incognita* or immature females of *R. reniformis*. One set of each accession was left uninoculated as a control. Each treatment, including the uninoculated control, was replicated six times. The experiment was terminated 3 months after inoculation, and the fresh mass of the plants was recorded. On the basis of disease development and reduction in plant mass, the accessions were classified into four categories: highly susceptible, susceptible, moderately resistant, and resistant (Anver 1990).

Results indicate that KA-3 exhibited resistant reaction to *M. incognita* but was susceptible to *R. reniformis* (Table 1). The variety KM-137 was resistant to *R. reinformis* and moderately resistant to *M. incognita* while KM-138 was moderately resistant to both the nematode species. The remaining varieties were either susceptible or highly susceptible to both the nematodes.

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Entomology

Tanaostigmodes cajaninae Promotes Pod Growth in Pigeonpea

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The pod wasp, *Tanaostigmodes cajaninae* LaSalle (Hymenoptera: Tanaostigmatidae), was first reported as a pest of pigeonpea (*Cajanus cajan*) in 1977 (Lateef 1977). It is widely distributed in India, but ocassionally causes serious damage to pigeonpea on research stations (ICRISAT 1988).

Lateef et al. (1985) described the biology of *T. cajaninae*. Eggs are laid on flowers and young pods of pigeonpea. Upon hatching the larvae enter the pod. Usually there is one larva per pod and it feeds on the seeds and/or inner pod wall. Pupation occurs within the pod and the adult emerges through a small hole made earlier in the pod wall. Lateef et al. (1985) reported that such pods fail to develop and may not be shed.

We observed stimulation of pod development when the ovaries of unopened pigeonpea flowers were infested with *T. cajaninae*. In the experiments on hybridization between *C. platycarpus* and *C. cajan*, pod formation was not observed on the hybrid plant unless it was backcrossed to either parent, because it was completely pollen sterile. However, *T. cajaninae* infestation has been recorded on *C. cajan*, the male parent used to produce the hybrid. In 1991, we observed pod development in F_1 hybrids and the pods were infested with *T. cajaninae* (Fig. 1a). The pods were small (Fig. 1b) and differed in shape when compared with the normal fertile pods.

During 1993, we recorded observations on the cause of pod formation in F_1 plants. Dissected pods showed unfertilized ovules (Fig. 1c). We observed larvae/pupae (Fig. 1d), and exit holes in most of the pods examined. Early instars of *T. cajaninae* larvae were observed in flower buds at pre-anthesis stage, indicating that the females laid eggs in the ovary before anthesis.

It is unclear why this phenomenon happened with such a high frequency (50% of flower buds) in this particular cross. We also do not know whether *T. cajaninae* females oviposit in unopened flower buds under field conditions, or whether the lack of young pods, due to infertility in this cross, forced females to select an alternative

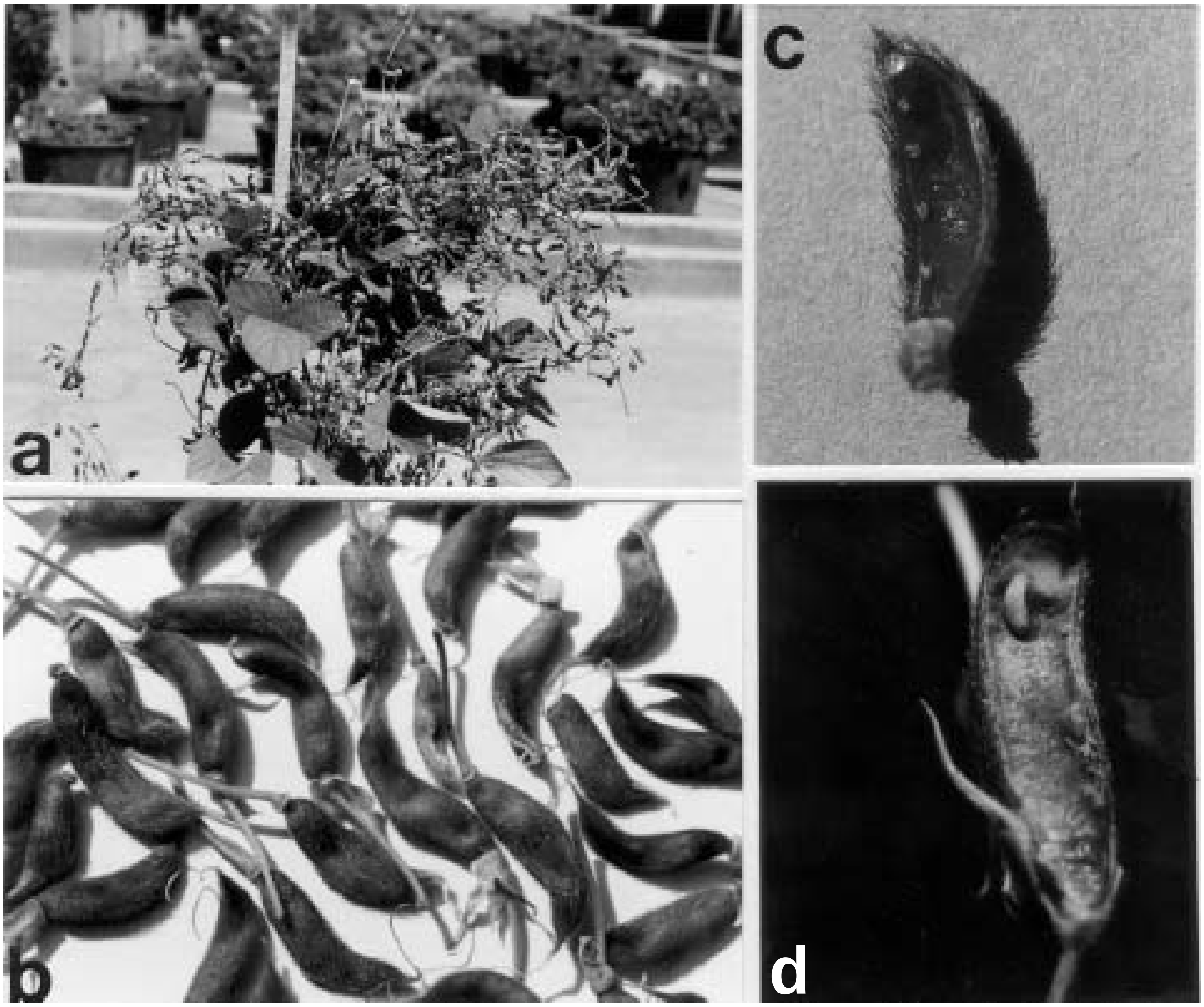

Figure 1. Pod formation induced by *Tanaostigmodes cajaninae* in the cross *Cajanus platycarpus* × *C. cajan*. (a) Hybrid plant with *T. cajaninae* induced pods; (b) Close-up of the pods; (c) Dissected pod showing unfertilized ovules; and (d) Dissected pod showing *T. cajaninae* pupa.

oviposition site. Perhaps the most intriguing question is how *T. cajaninae* induced pod development in an otherwise sterile cross.

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Survey of Reduviid Predators in Seven Pigeonpea Agroecosystems in Tirunelveli, Tamil Nadu, India

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Pigeonpea (*Cajanus cajan*) is one of the main pulse crops grown in Tamil Nadu, India. Insect pests are the major biotic constraints to pigeonpea production (Shanower et al. 1999). Several insecticides have been recommended for controlling the insect pests of pigeonpea. However, increasing concern for the degradation of environment, and the development of resistance in insect pests to insecticides (Armes et al. 1992) have prompted the search for more effective and ecofriendly alternatives for pest control. In pigeonpea insect pest management, lack of knowledge of predator population has hampered the integration of natural mortality factors into economic injury level assessments. Impact of predators on pest densities has been studied by several workers (Duffield 1994, Minja et al. 1999). Reduviids are common in pigeonpea fields and they feed on a number of insect pests (Ambrose and Claver 1995). However, their role in pigeonpea pest suppression has not been documented. Hence, an attempt was made to assess the distribution, diversity, and biocontrol efficacy of reduviid predators in pigeonpea agroecosystems in seven villages in Tirunelveli district, Tamil Nadu, India.

Weekly surveys were conducted during the pigeonpea-growing season in 1999–2000 to determine distribution and diversity of reduviid predators. Surveys were undertaken at seven villages, viz., Alangulam, Killikulam, Manimuthar, Panagudi, Shanmuganallur, Vannikonendal, and Virakeralampudur. Direct observations were made to estimate population density of reduviids in twenty plants per field, and ten fields per village. In addition to direct observations, mid-stem, leaves, and terminals of plants were selected at random to sample reduviid populations. Pigeonpea terminals were also swept with a sweepnet and examined for reduviids.

Reduviid populations were usually low and variable. Although, the composition of predacious reduviid fauna varied between geographical areas, the following species were predominant in pigeonpea agroecosytems: *Catamiarus brevipennis* Serville, *Coranus* sp, *Irantha armipes* Stal, *Rhynocoris fuscipes* Fabricius, *Rhynocoris kumarii* Ambrose and Livingstone, *Rhynocoris longifrons* Stal, and *Sycanus pyrrhomelas* Walker. Amongst these, *R. fuscipes* was the most abundant species in pigeonpea fields and the population was maximum in Alangulam. In Manimuthar the most abundant species on pigeonpea were *R. fuscipes*, *S. pyrrohomelas*, *I. armipes*, and *Coronus* sp.

Minja et al. (1999) reported substantial predation of insect pests of pigeonpea by the assassin bugs. Within pigeonpea fields, the relative mix of predacious reduviids varied with locality and season. Reduviids feed on a wide range of insect pests and their population levels increase following the buildup of their prey population (Ambrose and Claver 1997, Ambrose 1999).

Reduviid predators are much larger in size than other hemipteran predators such as *Nabis* (Nabidae), *Geocoris* (Lygaeidae), *Orius* (Anthocoridae), *Lygus* (Miridae), or *Podisus* (Pentatomidae) and are capable of successfully attacking and consuming larger preys (Schaefer 1988). Their abundance was higher than that of other hemipteran predators in the pigeonpea agroecosystems. Although quantitative assessment of the specific role of reduviid predators has not been determined, enough evidence is available on their impact on pigeonpea pests (Bhatnagar et al. 1983, Minja et al. 1999). Efforts should be made to mass rear these predators for field induction and establishment—a pomising field of research. Our ongoing studies suggest that it is feasible to mass rear reduviids for mass release. Successful conservation and augmentation of reduviid predators could be a rewarding excercise in pigeonpea pest management.

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Varietal Preference of *Clavigralla gibbosa* in Pigeonpea

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Among the pod damaging insect pests of pigeonpea, pod borer, podfly, and pod-sucking bugs (in order of importance) inflict heavy loss to seed yield. The tur pod bug, *Clavigralla gibbosa* Spinola is the most important pod-sucking bug in India (Reed et al. 1989). Though generally stated to be a minor pest it occupies an important position as a pest of pigeonpea (*Cajanus cajan*) because both nymphs and adults suck the sap from young seeds in the pods causing loss in seed mass and quality. Sengupta and Behura (1957) reported the occurrence of *C. gibbosa* on pigeonpea in the state of Orissa in India but no study on its varietal preference was done. However, other pod-sucking bugs such as *Anoplocnemis* spp and *Riptortus* spp occurred in negligible numbers in pigeonpea crop in Orissa.

Since *C. gibbosa* is predominant among sucking pests of pigeonpea the present study was taken up with 15 pigeonpea varieties and hybrids of short and medium duration suitable to this region along with a standard national check (UPAS 120). A field experiment was laid out at the Central Research Station Farm, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa, during 1998/99 rainy season. The crop was sown during the second fortnight of June following the recommended package of practice for the region in plots of 8 m × 5 m in a randomized complete block design having 15 entries replicated 3 times. The crop was unprotected throughout the period of investigation. Weekly observations on the population of *C. gibbosa* eggs, nymphs, and adults were recorded on 10 plants at random from 46th standard week of 1998 to 7th standard week of 1999; the data were then pooled for each variety. Seed yield was also recorded at harvest. The data on the pest population were suitably transformed for statistical comparisons following the procedures laid out by Gomez and Gomez (1984).

The number of eggs, nymphs, and adults present on the test varieties was significantly low compared to the check UPAS 120 (Table 1). The number of adults present varied from l.49 in AS 36 to 6.65 in UPAS 120 indicating differential preference for feeding and/or oviposition amongst varieties. This is supported by the fact that the number of eggs laid plant^{-1} varied from 3.50 in AS 36 to 20.10 in ICPL 151 amongst the test entries and was significantly lower than the check UPAS 120 (23.75). From the egg laying pattern it is evident that the ICPL determinate lines were moderately preferred for egg laying while the indeterminate hybrids were less preferred. The number of nymphs present on AS 36 was also the lowest whereas UPAS 120 recorded the highest population. The ICPL lines had a moderate nymph population while the hybrids maintained a low population. T 31, AS 36, and AS 46 were at par with each other having low number of nymphs. The egg:nymph ratio fluctuated from 0.76 to 1.53 amongst test entries indicating migration of nymphs from plant to plant and from variety to variety in search of the most preferred host.

Table 1. *Clavigralla gibbosa* population on pigeonpea varieties and hybrids and their yield performance at Bhubaneswar, Orissa, India during 1998/99 rainy season.

Entry	Days to 50% flowering	No. of eggs laid plant^{-1}	No. of nymphs plant^{-1}	Egg:nymph ratio	No. of adults plant^{-1}	Seed yield (kg ha^{-1})	Increase (%) in seed yield over check
Determinate lines							
ICPL 87	79	14.40	16.37	1.14	3.52	510.0	47.1
		(3.79)[1]	(4.04)		(1.87)		
ICPL 151	66	20.10	16.52	0.82	2.97	490.3	41.5
		(4.48)	(4.06)		(1.71)		
ICPL 87112	84	10.95	9.05	0.83	3.00	539.0	55.5
		(3.31)	(2.99)		(1.72)		
ICPL 86015	79	11.68	12.29	1.05	2.89	548.6	58.3
		(3.41)	(3.50)		(1.70)		
ICPL 187-1-1	79	9.39	7.97	0.85	2.81	660.3	90.5
		(3.06)	(2.82)		(1.67)		
Hybrids (Indeterminate)							
H 89-2	84	7.38	7.92	1.07	2.13	606.0	74.8
		(2.70)	(2.81)		(1.45)		
H 88-8	77	6.31	5.85	0.92	2.42	667.6	92.6
		(2.51)	(2.41)		(1.53)		
H 82-1	96	5.65	5.14	0.90	1.86	671.3	93.7
		(2.37)	(2.25)		(1.36)		
AKPH 1209	90	4.30	6.60	1.53	1.67	657.0	89.6
		(2.07)	(2.56)		(1.29)		
Others (Indeterminate)							
AKT 8912	80	9.76	11.73	1.20	2.40	533.3	53.9
		(3.12)	(3.41)		(1.54)		
TV 1	76	7.02	6.74	0.96	2.15	651.6	88.0
		(2.64)	(2.58)		(1.46)		
T 31	80	5.34	4.09	0.76	2.58	632.0	82.3
		(2.32)	(2.01)		(1.58)		
AS 36	77	3.50	3.38	0.96	1.49	763.3	120.1
		(1.86)	(1.83)		(1.21)		
AS 46	68	5.10	4.66	0.91	2.30	691.6	99.5
		(2.25)	(2.15)		(1.51)		
UPAS 120 (Check)	75	23.75	25.30	1.06	6.65	346.6	–
		(4.87)	(5.03)		(2.57)		
SEm ±		(0.12)	(0.13)		(0.09)	14.2	
CD (P = 0.05)		(0.35)	(0.38)		(0.26)	41.2	

1. Figures in parentheses are square root transformed values.

Seed yield was significantly the lowest (346.6 kg ha^{-1}) in UPAS 120 and highest (763.3 kg ha^{-1}) in AS 36. The increase in seed yield in AS 36 over the susceptible check was 120.1% (Table 1). Due to low population of bugs the hybrids generally yielded more than ICPL lines except ICPL 187-l-l .

Thus it may be concluded from the present study that the hybrids tested were less preferred by *C. gibbosa* than ICPL entries except ICPL 187-1-1. AS 36 was the most resistant variety to the bug with significantly high yield potential followed by AS 46 and hybrids (H 88-8, H 82-1, and AKPH 1209). These varieties and hybrids may be used as a major component of integrated pest management for *C. gibbosa* in Orissa.

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Extent of Raceme Damage by Web-forming Lepidopteran Pod Borers in Pigeonpea

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Pigeonpea (*Cajanus cajan*) is an important pulse crop of kharif (rainy) season in Orissa, India. Although the south coastal belt of Orissa experiences a regular incidence of web-forming lepidopteran pod borers on pigeonpea, the information on comparative damage potential of these species on a raceme is not known. An attempt was, therefore, made to assess the extent of raceme damage in early-, medium-, and late-maturing pigeonpea varieties

Table 1. Extent of raceme damage by pod borer species in pigeonpea in Orissa, India during 1994/95 and 1995/96 rainy season.

		Raceme damage[1] (%)					
		50% flowering stage			Pod-filling stage		
Pod borer species	Maturity group of the test variety	1994/95	1995/96	Mean	1994/95	1995/96	Mean
Maruca vitrata (a)	Early	5.18	7.63	6.41	10.66	18.52	14.59
	Medium	6.57	1.76	4.17	8.85	16.35	12.62
	Late	1.80	0.00	0.90	2.50	6.31	4.41
Nanaguna breviuscula (b)	Early	0.00	2.56	1.28	18.13	30.31	24.22
	Medium	7.98	0.00	3.99	9.77	17.12	13.45
	Late	3.16	0.00	1.58	4.30	8.50	6.40
Grapholita critica (c)	Early	3.03	4.86	3.95	5.84	8.50	7.17
	Medium	3.35	0.30	1.83	5.55	7.53	6.54
	Late	2.04	0.36	1.20	3.30	2.10	2.70
Borer complex (a+b+c)	Early	8.21	15.05	11.63	34.63	57.33	45.98
	Medium	17.90	2.06	9.98	24.17	41.00	32.59
	Late	7.00	0.36	3.68	10.10	10.51	10.31
SE ±	Early	2.11	2.05		5.00	8.01	
	Medium	1.90	0.72		1.51	4.05	
	Late	0.58	0.16		2.62	2.45	

1. Data is mean of 12 plants.

under the agroclimatic conditions of the south coastal belt of Orissa.

Three varieties, UPAS 120 (early), C 11 (medium), and PUSA 9 (late) were sown in strips of 20 m^2 under rainfed conditions in sandy loam soil (pH 6.9) during 1994 and 1995 at the Central Agriculture Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa. The extent of raceme damage (%) by the pod borers was recorded at 50% flowering and pod-filling stages by counting the total number of buds/flowers and number of buds/flowers webbed on 12 plant samples.

The pigeonpea racemes comprising leaves, buds, flowers, and pods were infested by *Maruca vitrata* Geyer, *Nanaguna breviuscula* Walker, and *Grapholita critica* Meyr. resulting in dropping of buds and flowers (Samalo and Patnaik 1984, Sekhar et al. 1991, Bajpai et al. 1995). At the 50% flowering stage, *M. vitrata* was the dominant species, which damaged 6.41, 4.17, and 0.90% racemes in early (UPAS 120), medium (C 11), and late (PUSA 9) varieties respectively (Table 1). *Nanaguna breviuscula* and *G. critica* infested 1.28–3.99% and 1.20–3.95% racemes respectively in different varieties. At the pod-filling stage in 1994/95 and 1995/96, *N. breviuscula* infested 4.30–18.13% and 8.50–30.31% of the racemes as against 2.50–10.66% and 6.31–18.52% by *M. vitrata*, and 3.30–5.84% and 2.10–8.50% by *G. critica* respectively.

The early-maturing variety was more prone to damage by the pod borers (45.98%) in comparison to medium- (32.59%) and late-maturing (10.31%) varieties at both the stages. *Maruca vitrata* at 50% flowering in early variety and *N. breviuscula* at pod-filling stage in the medium-maturing vareity were the dominant species. On the contrary in late-maturing variety, *N. breviuscula* was the major web-forming species in both the flowering and the pod-filling stages.

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Insect Pests of Pigeonpea in South Africa: Survey Report

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Pigeonpea (*Cajanus cajan*) is not widely cultivated in South Africa. But there is great demand for its dry, split seeds called "oil-dhal" by the local Asian community. Preliminary investigations by the authors (C Mathews and K B Saxena) on the marketing and utilization of this crop showed that about 120–150 tonnes of “oil-dhal” is imported from Malawi each month to meet the needs of over a million Indians living in South Africa. The total value of the imports is around US$ 1 million annually. The entire pigeonpea crop produced around house gardens locally is utilized as green vegetable by the Asian community and the whole dry seeds for making soup by the local African community.

From time to time, a few agricultural organizations in South Africa have undertaken research activities on specific aspects such as germplasm collection and description, use as forage crop, and local adaptability. A total of 672 pigeonpea germplasm accessions have been collected and preserved by the South African Gene Bank in Pretoria (van den Heever and Trytsman 2000). Pigeonpea is basically a low input, subsistence crop; as a result, the national research institutes did very little to popularize it among the South African farmers. During the late 1980s, efforts to introduce pigeonpea into the local smallholder farming systems were initiated by Brian Beck of the Provincial Research Unit in Mpumalanga using the short-duration cultivar Hunt. The farmers, however, rejected it because of the long cooking time required for its preparation. In 1992, eight improved genotypes from ICRISAT were tested in a farmer’s plot, 100 km east of Nelspruit. Unfortunately, the entire crop was destroyed by cattle. Pigeonpea research received attention again in 1998, with the aim of providing a multiple usage crop to the smallholder, resource-poor, dryland farmers in Mpumalanga. Formal trials to evaluate performance of 9 short-duration, 5 medium-duration, and 3 long-duration ICRISAT genotypes commenced in 1998.

Over 200 species of insects feeding on pigeonpeas have been recorded in India alone (Lateef and Reed 1990). Most of these, especially the foliar feeding insects do not cause serious economic damage, and are considered as minor pests. Studies in India have shown that the removal of up to 75% of pigeonpea leaves for extensive periods did not result in significant yield losses, and that most of the pigeonpea genotypes produce abundant buds and flowers and a large proportion of these will normally be shed (Sheldrake et al. 1979). Thus, pigeonpea plants are able to give satisfactory yields even after a large proportion of their buds and flowers have been damaged by insect pests. These plants, especially the indeterminate types, produce new growth with the potential to compensate for the previous losses under favorable climatic conditions.

The insects that attack the pods are considered the most important pests of pigeonpea. Pod borers (including *Helicoverpa armigera* and *Maruca vitrata*) and pod-sucking bugs (mainly *Clavigralla* spp) are the major pests in these groups. The pod borer *H. armigera* is the most important constraint to pigeonpea production throughout South Asia (Ranga Rao and Shanower 1999). The larvae of this insect destroy buds, flowers, and pods. They attack leaves in the absence of the floral organs. *Maruca* larva feeds from inside a webbed mass of leaves and it becomes a menace early in the season especially in areas with high humidity. The adults and nymphs of the pod-sucking bugs (*Clavigralla* spp and *Nezara viridula*) pierce the pod wall and suck the fluid from the developing seeds. The attacked seeds shrivel and develop dark patches. These pests are very common in Africa and Asia, particularly in dry seasons (Reed and Lateef 1990). Aphids colonize the young shoots, flowers, and pods. The young leaves of seedlings become twisted under heavy infestation and wilt when the plant is under moisture stress. The scale insects such as *Icerya purchasi* suck fluids in the stems and occasionally in the leaves. Thrips and blister beetles normally attack the flowers and heavy infestation may lead to flower drop. Infestation by bruchids (*Callosobruchus* spp) starts in the field. The infested seeds lose their viability and are unfit for human consumption. Delayed harvesting, poor drying, and storage facilities can lead to total loss of pigeonpea grain due to this pest.

In May 2000, a team of scientists visited trial sites and farmers' fields to monitor the pigeonpea crop, especially with respect to the biotic and abiotic stress problems, which should be addressed in future work. The observations made on the incidence of insect pests of pigeonpea for the first time in South Africa are summarized in this short note.

The pigeonpea trials and farmers' plots located at White River, Nelspruit, Malekutu, Phola, and Mzinti in Mpumalanga Province; at Cedara in Pietermaritzburg and Mariannhill near Durban in the Kwazulu-Natal Province; and at the Agricultural Research Council (ARC), Roodeplaat near Pretoria were visited.

In a non-governmental organization (NGO) project at Mariannhill, the long-duration pigeonpea landraces were included in the cropping system for the first time in 1999. The presence of the pod borer (*H. armigera*) and aphids were observed on pigeonpea at this site. At Cedara, the 2- to 3-year-old long-duration landraces were established as hedgerow and they were free of insect pests. At Roodeplaat, pigeonpea cultivars were maintained as part of germplasm preservation. The plants appeared to be at least 2–3 years old and were free of insect pests during the visit.

The major insect pests present in the trial plots in Mpumalanga during 1998/99 season were the pod borer (*H. armigera*) and pod-sucking bugs (*Clavigralla* spp). Three sprays with cyhalothrin (Karate®) on the short-duration genotypes, and once on the medium- and long-duration genotypes effectively controlled these insects. These two pests were observed at all sites in Mpumalanga.

Observations during 1999/2000 season showed that the species of insect pests and the severity of damage on pigeonpea have increased considerably from the previous season. The damage caused by insect pests on flowers and pods were more severe on the short-duration types than the long- and medium-duration types. All the insects listed below except the scale insect were present on the short-duration types during the 1999/2000 season. The incidence of insect pests was comparatively low on the medium- and long-duration genotypes and a satisfactory crop was obtained from these without the use of any chemical sprays. The differences in pest incidence between the pigeonpea maturity groups may be due to the cooler, winter environment that prevails during the flowering and podding stages of these genotypes compared to the short-duration group. Insect pests are most active in warm and humid environments. Similar observations have been made on pigeonpea in other parts of southern and eastern Africa (Minja et al. 1999).

The major insects observed on pigeonpea in South Africa were: *Clavigralla* spp, *H. armigera,* and bruchids (*Callosobruchus* spp). These pests were present in large populations and they caused serious yield losses locally although the losses have not been quantified. *Maruca* was only found in the short-duration genotypes at Malekutu. Minor pests included *N. viridula*, *M. vitrata*, *Aphis* spp, jassids (*Empoasca kerri*), scale insect (*I. purchasi*), thrips (*Megalurothrips usitatus*), and blister beetles (*Mylabris* spp), which apart from the green aphids, were only restricted to certain localities in Mpumalanga.

These preliminary results indicate:

- Studies to estimate the potential yield losses caused by these insect pests in different pigeonpea genotypes should be undertaken.
- Chemical control is considered as the most efficient method employed to control these insect pests. However, the resource-poor farmers who are being targeted to adopt this crop in South Africa will find chemical control a difficult option.
- There is therefore, a great need to develop affordable integrated pest management strategies involving cultural, genetic, and biological approaches for the successful promotion of this crop in South Africa.

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Agronomy

Evaluation of Pigeonpea Genotypes for Rainfed Conditions in the Southern Zone of Andhra Pradesh, India

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Pigeonpea (*Cajanus cajan*) is an important pulse crop grown in the rainy season in Andhra Pradesh, India. It is grown in an area of 0.35 million ha in Andhra Pradesh. In the Southern Zone of Andhra Pradesh, pigeonpea is grown as an intercrop with rainfed groundnut (*Arachis hypogaea*) in different ratios, i.e., 1:11, 1:15, and 1:23. Whenever the Southwest monsoon is delayed or fails, pigeonpea is found to be the most remunerative contingent crop and can be grown as sole crop with a spacing of 60 × 20 cm during August in red soils of this zone by taking advantage of the Northeast monsoon which contributes about 45–50% of total rainfal of this zone (ANGRAU 1995). The average rainfall over the past ten years is 1075.6 mm. The high yield potential of pigeonpea crop (around 2.0 t ha^{-1}) has not reflected in increased productivity of this crop in farmers' fields. This might be due to cultivation of traditional varieties and also

Table 1. Performance of pigeonpea genotypes during rainy season in 1996–98 at Tirupati, Andhra Pradesh, India.

	Seed yield (t ha^{-1})			
Genotype	1996	1997	1998	Mean
LRG 30	1.7	1.1	1.8	1.5
ICPL 332	1.3	0.9	1.7	1.3
ICPL 87119	1.2	0.9	1.0	1.0
ICP 8863	0.8	1.0	1.3	1.0
MRG 66	1.4	0.7	1.2	1.1
ICPL 85063	1.1	0.8	1.2	1.0
Selection No. 17	1.3	0.9	1.2	1.1
Selection No. 27	1.3	0.9	1.1	1.1
ICPL 87051	0.7	0.8	1.0	0.8
Local variety	0.7	0.8	0.9	0.8
Mean	1.1	0.9	1.3	–
SEm ±	0.071	0.083	1.76	
CV (%)	0.07	0.14	0.13	

Table 2. Morphological characters of pigeonpea genotypes in a field trial at Tirupati, Andhra Pradesh, India during 1996–98.

Genotype	Days to flowering	Days to maturity	Plant height (cm)	No.of branches plant^{-1}	100-seed mass (g)
LRG 30	115	185	241	18	10.6
ICPL 332	118	189	250	18	9.9
ICPL 87119	120	193	229	16	10.2
ICP 8863	106	182	220	14	8.5
MRG 66	119	184	246	15	8.7
ICPL 85063	114	189	246	12	8.2
Selection No. 17	119	188	235	14	8.4
Selection No. 27	119	189	221	16	9.1
ICPL 87051	116	186	219	12	9.8
Local variety	90	150	145	16	6.5
SEm ±	0.91	0.43	1.72	0.28	0.08
CV (%)	1.3	0.4	1.3	3.2	1.7

because the crop suffers from various stresses (climatic, edaphic, or biological). Stability in production is much influenced by high incidence of insect pests, particularly pod borers (Jain 1975).

Early-maturing varieties (e.g., HY 4, T 21, BDN 1, ICPL 95) tested at the Regional Agricultural Research Station, Tirupati, Andhra Pradesh are not performing well when sown at the onset of rainy season as heavy rains (Northeast monsoon) are received in October/November at the time of flowering and podding of these varieties (ANGRAU 1990). When early varieties were introduced in areas with rainfall above 1000 mm, they failed to respond well owing to heavy pest damage and flower and fruit drop as a result of late rains. It is, therefore, necessary that varietal recommendations in case of pigeonpea must be carefully studied for each agroclimatic situation. So identification of high-yielding medium-duration varieties suitable as sole crop for sowing in late rainy season would greatly enhance the productivity and area of pigeonpea crop. For this purpose a field experiment was conducted from 1996 to 1998 with ten medium-duration genotypes. The experiments were sown in the second fortnight of August with inter-row spacing of 60 cm and intra-row spacing of 20 cm. The plot size of 4 m × 3.6 m with 6 rows, each 4 m long was maintained and the crop was fertilized with 20 kg nitrogen ha^{-1} and 50 kg P_2O_5 ha^{-1}. To control pod borers, first spray was given with monocrotophos at flowering stage and second spray with chlorpyriphos at pod developemt stage of the crop. Observations on plant height, number of branches plant^{-1}, and time to flowering were recorded on ten plants selected at random from each plot. Duration from date of sowing to date of 50% flowering in the genotype was taken as days to 50% flowering. Plant height was measured at maturity from bottom of the plant to the tip of the plant (main axis).

Mean performance of pigeonpea genotypes for yield and other yield attributes is presented in Tables 1 and 2. In 1996 and 1998 highest seed yield was 1.7 t ha^{-1} and 1.8 t ha^{-1} respectively (Table 1). Due to heavy rains in December 1997 (202 mm in 8 rainy days as against mean 98 mm in 4 rainy days), severe flower drop occurred even in medium-duration varieties which resulted in poor seed yield of a maximum 1.1 t ha^{-1} in LRG 30. The locally grown pigeonpea variety was early (90 days) in flowering and matured by 150 days compared to other test genotypes (Table 2). Plant height ranged from 145 cm (local variety) to 250 cm (ICPL 332). Highest number of branches plant^{-1} (18) was recorded in LRG 30 and ICPL 332. Hundred-seed mass varied from 6.5 g (local variety) to 10.6 g (LRG 30). Medium-duration varieties with indeterminate growth habit have shown better stability in performance as compared to locally grown traditional variety because the latter has restricted pod bearing length and less crowded pods. Late rains in October–December at the time of flowering and podding increased damage by pod borers (Jeswant and Baldev 1990).

The present study suggests that to take advantage of the Northeast monsoon medium-duration pigeonpea varieties (180 days) LRG 30 and ICPL 332 can be sown late in August in the Southern Zone of Andhra Pradesh characterized by high rainfall. Under these conditions the crop is manageable and gives good seed yields.

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Maize and Pigeonpea Intercropping Systems in Mpumalanga, South Africa

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Pigeonpea (*Cajanus cajan*) is one of the major pulse crops of the tropical and subtropical regions of Asia, Africa, and the Caribbean. In South Africa, it is usually grown singly or as a hedge plant in home gardens or around the sugarcane (*Saccharum officinarum*) fields. Being one of the most drought tolerant legumes, pigeonpea has a great potential to increase the sustainability of cropping systems in the arid and semi-arid regions. In India, pigeonpea is generally intercropped with cereals, other legumes, cotton (*Gossypium* sp), and castor (*Ricinus communis*) (Saxena 1999). As intercropping is an important aspect of smallholder-farmer crop production systems, a study was initiated to evaluate the performance of pigeonpea cultivars with varying maturity periods with maize (*Zea mays*) in two intercropping systems.

Maize is the major cereal grown by the smallholder farmers in Mpumalanga in South Africa. The short-duration (SD) CIMMYT maize composite EWF-2 was intercropped in two trials, one with the SD cultivars ICPL 87091 and ICPL 87105, and a second one with the long-duration (LD) cutivar ICEAP 00040 and medium-duration (MD) cultivar ICP 6927. Two intercropping systems, the alley planting and same row planting systems with maize, were evaluated in these trials using randomized complete block design with four replications during the 1998/99 season at Malekutu (25°12’ S and 31°12’ E at 350 m above sea level) in Nsikazi District of Mpumalanga Province. In the alley planting system, two pigeonpea rows were planted after every three maize rows. In the second intercropping system, maize and pigeonpea were planted on the same row maintaining the plant populations at sole cropping. In the SD trial, seeds were sown 10 cm apart in rows spaced at 70 cm. In the LD-MD trial, plant spacing was 70 cm in rows spaced at 90 cm with 2 plants at each station. The LD trial was planted in mid-December 1998, and the SD trial in the first week of January 1999. Insect pests mainly the pod-sucking bugs and pod borers were controlled by spraying the insecticide Karate® (cyhalothrin) once in the LD-MD trial and three times in the SD trial. The data were analyzed using the MSTAT-C program.

Yields of both maize and pigeonpea in intercropping systems were generally lower than in monocropping systems in both the trials (Table 1). The yield reduction in the intercropping systems for LD and MD pigeonpea cultivars ranged from 7.4% to 31.0%, while that of maize ranged from 8.7% to 38.6% (Table 2). In the SD trial, the reduction in yield ranged from 36.8% to 66.3% in pigeonpea and from 12.9% to 41.9% in maize (Table 2); also the yield reduction in both maize and pigeonpea was significant. For MD and LD cultivars, there was a significant yield reduction under alley planting system. The average land equivalent ratio (LER) was the same (1.24) in both the systems in the SD trial. In the LD-MD trial, the average LER was 1.37 in the alley system and 1.77 when intercropped on the same row with maize.

These findings are in conformity with the results obtained from similar alley cropping studies carried out in India and Sri Lanka in the past. Intercropping had little effect on sorghum (*Sorghum bicolor*) yields, but pigeonpea yields were reduced by 21% (Abeyaratne 1956). Saxena et al. (1998) found that a combination of 75% maize and 25% pigeonpea had an 8% advantage in land use. Intercropping yields reduced maize yields by 5–23% and pigeonpea yield by 11–78% in another study in Sri Lanka (Saxena 1999). In general, the LD and MD pigeonpea cultivars are best adapted to intercropping as they mature later than maize. Being deep-rooted they make use of the moisture reserve, which would otherwise be unutilized.

Table 1. Yields of maize and pigeonpea in intercropping systems at Malekutu, Mpumalanga, South Africa, 1998/99[1].

Cropping system[2]	SD pigeonpea cultivars	LD and MD pigeonpea cultivars	Yield in SD trial (kg ha^{-1})		Yield in LD-MD trial (kg ha^{-1})	
			Maize	Pigeonpea	Maize	Pigeonpea
Maize + pigeonpea in the same row	ICPL 87105	ICEAP 00040	1966	458	2594	1204
Maize + pigeonpea in the same row	ICPL 87091	ICP 6927	1856	606	2882	1207
3 rows of maize + 2 rows of pigeonpea (3:2 alley)	ICPL 87105	ICEAP 00040	1312	822	2011	891
3 rows of maize + 2 rows of pigeonpea (3:2 alley)	ICPL 87091	ICP 6927	1483	852	1935	959
Sole maize			3257	–	3154	–
Sole pigeonpea	ICPL 87105	ICEAP 00040	–	1360	–	1300
Sole pigeonpea	ICPL 87091	ICP 6927	–	1349	–	1379
Mean			1775	907	2515	1157
CV (%)			7.80	35.2	17.06	17.83
LSD (P = 0.05)			186	421	661	311

1. SD = Short-duration; MD = Medium-duration; and LD = Long-duration.
2. Maize cultivar EWF-2 was tested.

Table 2. Yields of maize and pigeonpea in two intercropping systems compared with sole crop yields at Malekutu, Mpumalanga, South Africa, 1998/99.

Cropping system[1]	SD trial[2]			LD-MD trial[3]		
	ICPL 87105	ICPL 87091	Mean	ICEAP 00040	ICP 6297	Mean
Pigeonpea yield reduction (%)						
1:1 same row (maize + pigeonpea)	66.3	55.1	60.7	7.4	12.0	9.5
3:2 alley (maize + pigeonpea)	39.6	36.8	38.2	31.0	20.0	25.5
Mean	52.9	45.9	49.5	19.0	16.0	17.5
Maize yield reduction (%)						
1:1 same row (maize + pigeonpea)	12.9	17.8	15.4	17.8	8.7	13.4
3:2 alley (maize + pigeonpea)	41.9	34.3	38.1	36.2	38.6	37.4
Mean	27.4	26.1	26.8	27.0	23.7	25.4

1. Maize cultivar EWF-2 was tested.
2. Short-duration (SD) pigeonpea cultivars were tested.
3. Long-duration (LD) and medium-duration (MD) pigeonpea cultivars were tested.

The results from the current study showed that intercropping of maize, especially with LD and MD pigeonpea cultivars, was a useful practice towards increasing profitability of the dryland cropping systems. However, there is a need to determine the most suitable crop combinations and the systems acceptable to the dryland farmers in Mpumalanga to maximize the advantage of land use.

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Utilization

Pigeonpea: A Potential Fodder Crop for Guangxi Province of China

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Globally, pigeonpea (*Cajanus cajan*) is grown in about 20 countries on 5.4 million ha (Saxena 1999) and the entire production is consumed as food. Special efforts are being made in China to exploit the potential of pigeonpea as a fodder crop. This article reviews the progress and discusses the prospects of pigeonpea as a major fodder crop.

In China, Guangxi is the most important province for livestock since its rural economy heavily relies on animal husbandry. For a sustainable rural animal industry in the province, the availability of quality fodder and feed throughout the year is very critical. The provincial government, therefore, spends large amount of resources to import maize (*Zea mays*) and rice (*Oryza sativa*) from other provinces and international markets for feeding the livestock (Chengbin et al. 1999). On the other hand large areas of mountain slopes are lying fallow because they are unfit for the cultivation of food crops. To deal with the critical situation it has been decided to increase the population of fodder eating animals such as goat, cattle, and buffalo and reduce the emphasis on grain feeding animals. At present the population of cattle and buffalo in the province is about 8 million (Mucheng and Xinhua 1997). To further enhance the animal population, the provincial government has launched a special 'Million Goat Project' in Hechi prefecture for promoting export meat market. Under this project, the population of goat will be increased to one million within a target period of three years.

Pigeonpea has been identified to meet the growing needs of fresh quality fodder because it grows well in the eroded soils of hilly regions and can provide good quality fodder under dry conditions. Its ability to allow 3–5 fodder cuttings make it a very useful crop for stall feeding. Pigeonpea, a perennial drought tolerant crop, has shown high adaptation in a range of soil types of mountain regions of Du Au, Dahua, Huan Jiang, and Feng Shan counties of Guangxi Province. According to Fuji and Zhenghong (1995) the foliage of pigeonpea is a quality fodder and goats (Fig. 1), buffalo, cattle, and pig relish it.

Figure 1. Stall feeding of goats in China with pigeonpea fodder.

A preliminary evaluation of ICRISAT pigeonpea varieties at Guangxi Academy of Agricultural Sciences, Nanning, China showed that ICPL 93047 produced 54 t ha^{-1} of green fodder in five cuttings and 29 t ha^{-1} of dry fodder (Shiying et al. 1999). In an experiment at Langan County sown in June 1999, about 52 t ha^{-1} fodder was harvested in five cuttings. This experiment also showed that pigeonpea can grow well during winter when normal fodder supply is limited. It is expected to meet the fodder needs in Guangxi Province for cooler season. It is observed that the goat and cattle like dry forage of pigeonpea better than green matter. The natural land resources of Guangxi Province is suitable for pigeonpea cultivation for both fodder production and soil conservation. It is estimated that about 6.5 million ha of waste mountain slopes are available for exploitation by crops like pigeonpea. It is likely that in near future pigeonpea fodder production may shape into a large agro-industry in the region, which can stimulate further commercial animal husbandry in Guangxi province for generating income.

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Traditional and Alternative Uses of Pigeonpea in China

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Pigeonpea (*Cajanus cajan*) was introduced to China from the eastern parts of India about 1500 years ago (Zhoujie 1997). Traditionally, it has been used for lac production, fuel wood, soil conservation, fodder, food, and medicine. Its food uses are constrained by some prominent defects in the landraces. These include long-duration (more than 300 days), inherent low seed yield (750 kg ha^{-1}), small seed size, and high amount of trypsin inhibitor. To overcome these constraints, new varieties of pigeonpea have been introduced recently into China from ICRISAT. These varieties are showing good adaptation and have many useful traits (Shiying et al. 1999). Therefore, new uses of this crop need to be identified. This paper reviews the traditional uses of pigeonpea in China and highlights the potential uses identified recently from the research work done in this area.

Lac Production

The most important purpose of pigeonpea cultivation in China is to inoculate the lac insect (*Kerria lacca* Kerr.) on the shoots of one-year-old pigeonpea plants for production of lac. Pigeonpea is preferred for lac production because it has relatively faster growth rate that allows lac harvest at least one year ahead of other perennial hosts. According to Yude et al. (1993) pigeonpea not only produces high yields (750 kg ha^{-1}) of lac but the quality of lac is also superior which fetches better price in international market. A survey of Yunnan Province, China conducted in 1989, showed that pigeonpea occupied about 3500 ha land and majority of it was under lac cultivation. For over 40 years, pigeonpea was a major income generating source for the farmers in the southern provinces of China.

Fuel Wood

Pigeonpea produces a significant amount of biomass and after the primary use of the crop, its dry shoots are invariably used as fuel wood. In the lac-growing areas, after harvesting lac resin from the shoots the pigeonpea plants are chopped and dried for use as fuel. On average, 1 ha of pigeonpea crop produces about 6 t of fuel wood (Zhenghong and Fuji 1997). According to Yude et al. (1993) the quality of pigeonpea fuel wood has been estimated to be excellent, yielding energy at the rate of 4350 K cal kg^{-1}. In the low mountain ranges of China, where pigeonpea is not cultivated for lac production, the farmers grow pigeonpea on wastelands and field bunds. After harvesting seeds for feed purpose, the plants are cut and used for fuel. Pigeonpea, therefore, has contributed significantly in providing relief from the energy crises. In rural China, pigeonpea fulfils the needs of fuel wood and helps in arresting deforestation.

Soil Conservation

In the recent past, the ecology of arid-hot regions of southern China has been severely damaged, and scientists believe that its recovery is not easy due to prevailing climatic and soil conditions and high population pressure. Screening of suitable forest tree species for these harsh climates is also not meeting with desired success. This problem has bothered the forestry department for many years. Some shrub species such as *Emblica officinalis*, *Dodonaea viscosa*, and *Tephrosia candida* used for forestation, grow slowly and have low or no economic value. Pigeonpea not only grows well in these areas due to its better adaptability to degraded soils and drought tolerance but also grows relatively faster to cover the bare land. The crop can easily be adopted by local people due to its potential uses. Therefore, pigeonpea has been

Figure 1. Pigeonpea grown on riverbed in China to control soil erosion.

identified as an important species for afforestation in China. At present, there are more than 700 ha of forest land planted with perennial pigeonpea for soil conservation in Yunnan Province. It has also been selected as the forestation species in the major government reconstruction projects such as "Protection of forest in the upper-middle reaches of Yangzi River", "Protection of forest in Lancangjiang River", and "Protection of natural forest" (Fig. 1).

Forestry Product

Jianyun and Yun (1998) conducted studies on the processing technology of plywood bond using pigeonpea glue. The results showed that the bond strength of the plywood was 1.28–1.92 MPa and it was higher than that of soybean glue. These parameters meet the National Standards. Jianyun and Yun (1998) also recommended that pigeonpea could be used as a substitute for soybean in plywood processing. In comparison to soybean (*Glycine max*) the glue processing technology using pigeonpea is relatively simpler and economical.

Folk Medicine

According to Dihua et al. (1985) and Shaomei et al. (1995) the old Chinese literature has description of significant curative effects of various pigeonpea plant parts. The root is used to treat febrile diseases and relieve internal fever, constrict tissue for controlling bleeding, and destroy internal worms. The leaves can be used to treat jaundice, trauma, and cough. Some hospitals in Hainan Province are still using pigeonpea to treat trauma, burn infection, and bedsore. Dihua et al. (1985) identified some useful chemical compounds in pigeonpea leaves such as salicylic acid, hentricacontane, 2-carboxyl-3-hydroxy-4-iso-prenyl-5-methoxy-stilbene, laccerol, longistyline A, pinostrobin, sitosterol, longistyline C, naringenin-4', 7-dimethyl ether, and ß-amyrin. The pharmacology and toxicology tests conducted on rats demonstrated that the curative effects of cajanian on inflammation are more prominent than that of salicylic acid and its toxicity is less than that of salicylic acid (Shaomei et al. 1995).

Fodder and Feed

Use of pigeonpea seeds and green foliage as feed and fodder is a common practice in rural China. As feed, the seed is primarily fed to pigs and chickens and sometimes to cattle and goats too. For pigs, the boiled seeds of pigeonpea are used to prepare feed mixtures with other ingredients while raw seeds are fed to chickens. Generally, cattle and goat graze on the standing pigeonpea crop and eat its fresh young leaves and tender branches.

In 1992, the Institute of Insect Resources and Agricultural University of Yunnan jointly studied the nutritional value of pigeonpea feed experiments. In this experiment pigs were fed with feed mixtures prepared with different levels of pigeonpea (Fuji et al. 1995). The results showed that during the entire period of experimentation the health of the test animals was normal with no sign of illness. It was also reported that meal mixture containing 6–12% pigeonpea increased meat mass. The gain in the meat mass production was 78 g day^{-1} with a ratio of meat mass to feed input of 3.54:1. This efficiency mark achieved with pigeonpea matched with the National Standards. Based on this information, Fuji et al. (1995) developed various feed mixtures using pigeonpea seed (22% protein) and dry leaf powder (19% protein) as major source of protein.

Food

Although pigeonpea was not liked by Chinese as food, during the famine years of 1950s and 1960s the local people in parts of China ate pigeonpea seeds in their main cuisine. As a substitute for soybean it was also used in making sauce and bean curd. Generally speaking, the seeds of landraces are not acceptable as food due to their small size, high amount of trypsin inhibitor, long cooking time, and puckery and odd taste in green (immature) and dry seed respectively. In the on-going pigeonpea development program in Yunnan Province ICRISAT's new varieties are performing well and their seed quality is acceptable. Therefore, to make their production sustainable new uses of its consumption need to be invented.

Several new processing technologies of products such as spicy-crisp pigeonpea, sweet bean paste, and pigeonpea starch were developed in China (Jianyun et al. 2000). The spicy-crisp pigeonpea was made through procedures of steeping, selection, and frying. The product is crisp and has nice taste with special flavor which met the National Standards. The sweet bean paste is of golden yellow color and tastes good and feels smooth. The starch products made from pigeonpea were found better in sensory index when compared with broad bean (*Vicia faba*).

Other Potential Uses

Vegetable. Chinese generally consume a great deal of fresh legume vegetables everyday. Owing to their large seed size, pleasant flavor (sweet), and green color of immature seeds, the recent ICRISAT pigeonpea varieties have a potential of becoming a popular vegetable in China. The range of maturity available in the germplasm can provide fresh peas for consumption over a long period of time. The short-duration types can be grown around in peri-urban areas. The medium-duration types could be intercropped with cereals in farm lands while long-duration types are ideal for soil conservation. The green pods in these cropping systems can be harvested as a vegetable. Vegetable pigeonpea is very nutritive (Faris et al. 1987) and this will provide much needed vital nutrients to the rural masses.

Snacks. At present a variety of snacks made from cereals, legumes, and fruits are available in the Chinese market. Since pigeonpea seed contains 22% protein and 8 important amino acids, necessary for the human body, its snacks and other processed products will be able to compete well in this enormous market. Some of the products which have good potential include spicy-crisp grains, pigeonpea sweet paste, and noodles. The processing technology for spicy-crisp pigeonpea is established and it could be utilized immediately. There is a great deal of demand for sweet bean paste in China before the Mid-Autumn Festival every year. In the past China had imported pigeonpea sweet paste to produce high-grade "moon" cake. There is an apparent demand for this product in the market.

In China, legume noodles are made from mung bean (*Vigna radiata*) and broad bean and they have a good market. At ICRISAT, a technology to prepare high quality noodles from pigeonpea has been developed and it can be transferred to China. It is believed that this product will certainly find a place in the market.

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Pigeonpea: An Excellent Host for Lac Production

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Pigeonpea (*Cajanus cajan*) was introduced into China sometime in the 6th century from India and since then it was cultivated sporadically in the southern provinces. In the 1950s, pigeonpea was identified as a favorable host for lac insect (*Kerria lacca* Kerr.) in Yunnan Province, China because it was found to have good characters such as fast growth, and high yields of quality lac. Also, the crop is easily cultivated. Scientists at the Lac Research Station, located in Jingdong in Yunnan Province, played a leading role in the research and development of this crop. During the past 50 years, a lot of research has been conducted on various aspects of lac production and most reports and research papers have been published in Chinese language in the local journals. To benefit pigeonpea researchers outside China, an attempt has been made to review the major research findings related to the use of pigeonpea as host for lac production.

In Yunnan Province, pigeonpea cultivation became popular among the farmers. According to Yude et al. (1993), in the Yunnan Province alone pigeonpea occupied about 3500 ha in 1989. The average lac yield was about 750 kg ha^{-1} (Anonymous 1978, Yunzheng et al. 1980, Lisa and Kaigui 1980). The high profitability of the crop helped spreading pigeonpea cultivation in the neighboring provinces. In the next decade pigeonpea cultivation met with a serious set back due to severe downfall in the demand of lac in the international market and this resulted in abandoning of the commercial cultivation of pigeonpea in China.

Adaptation and Agronomy

Pigeonpea cultivation in China was restricted to the frost-free areas of arid, semi-arid tropical, and sub-tropical regions of southern provinces. Traditionally, the crop is sown during rainy season which begins in the month of May and extends up to July. The sowings were done in hills, with inter-row spacing of 120–150 cm and plant spacing of 100 cm. Some farmers also adopted intensive cultivation with inter-row spacing of 200 cm and plants within rows spaced at 50 cm. About 3–5 seeds of pigeonpea were sown in each hill applied with about 500 g of farmyard manure before sowing. After one month, thinning was done and only two seedlings were retained in each hill. Generally two weedings were carried out and the plants were pinched (removing growing tips of the seedlings) during early stages of growth to enhance the production of primary branches.

For lac production, one-year-old plants were used. For summer crop of lac, the brood lac was bound on the stem below the first branch in May. Similarly for a winter crop, the broods were bound in the month of October. For this purpose 5–9 suitable branches with more than 0.8 cm diameter were selected. Since the brood lac is bound below the first primary branch, larvae of the lac insect swarm spontaneously to settle down on the branches to secrete lac which is deposited around the branches or stem. The summer crop of lac is harvested in October while the lac harvesting of winter crop is done in May.

Population Responses

Traditionally, long-duration pigeonpea was cultivated at 1×1.5 m spacing at two plants per hill resulting in a population of 13320 plants ha^{-1}. From this crop, an estimated 39960 suitable branches can be obtained for lac production with a total branch length of 35164 m ha^{-1}. Yunzheng et al. (1980) compared different pigeonpea population densities by using spacing 0.5×2 m (19980 plants ha^{-1}), 1×1.5 m (13320 plants ha^{-1}), and 1×2 m (9990 plants ha^{-1}) for the total branch length available for lac production. The results showed positive relationship between plant population and number and total length of useful branches. At the population of 19980 plants ha^{-1}, 79920 suitable branches were produced with a total branch useful length of 80719 m ha^{-1}. It was interesting to note that a plant population of 9990 plant ha^{-1} produced more number (49950) of usable branches with more (46153 m) total branch length than higher plant population (13320), which yielded only 39960 branches and 35165 m branch length in one hectare.

Comparison with Other Hosts

Lisa and Kaigui (1980) compared the response of pigeonpea to brood lac production with other hosts such

Table 1. Comparative response of pigeonpea (*Cajanus cajan*) to brood lac production in Jingdong, China, 1964.

Description	Summer crop	Winter crop
Suitable parasitic rate[1] (%)	40–50	20–25
Suitable brood lac quantity per plant[2]		
Dalbergia szemaoensis	1/56	1/310
C. cajan	1/51	1/270
Eriolaena malvacea	1/30	1/150
Propagation capacity of brood lac[3]		
D. szemaoensis	1/73.6	1/29.8
C. cajan	1/70.5	1/31.5
E. malvacea	1/60.4	1/13.1
Lac yield (g plant^{-1})		
D. szemaoensis	370	220
C. cajan	270	40
E. malvacea	255	30

1. Calculated from ratio of shoot length settled by lac insects and the length of effective shoots. Effective shoots are those shoots with >0.8 cm diameter.
2. Ratio of the shoot length bound by brood lac and the length of effective shoots.
3. Ratio of the brood lac area and the settlement area by its descendants.

as *Dalbergia szemaoensis* and *Eriolaena malcacea*. They concluded that the suitable parasitic rate for each pigeonpea plant was 40–50% in summer crop and 20–25% in winter crop; the suitable brood lac quantity for each plant varied when different brood lac was used, and the best one was from *D. szemaoensis* due to the high gravid quantity per lac insect on it (Table 1).

Derrong and Wenliang (1985) compared the quality of lac harvested from pigeonpea plants for three years. They concluded that the quality of this lac was up to the National Standards. The important parameters of the lac produced on pigeonpea plants are summarized in Table 2.

Effect of Flower Removal on Yield and Quality of Brood Lac

Long-duration pigeonpea plants bear a lot of flowers and have a long blooming period in winter and early spring seasons. So they also produce a large number of pods. This results in depletion in the deposits of important inorganic elements and consequently the growth of lac insects reared on such plants is also restricted. This adversely affects the yield and quality of lac. Kaiwei et al. (1988) studied the effect of flower removal on the yield and quality of lac produced on pigeonpea. They reported that nitrogen, phosphorus (P), potassium, copper, molybdenum, and boron contents in the leaves increased

Table 2. The quality parameters of lac produced on pigeonpea plants during 1979–81 summer crop at Jingdong, China.

Year	Color index	Soluble material in cold alcohol (%)	Lac wax (%)	Water (%)	Softening point
1979	27.7	85.52	5.84	3.36	69.1
1980	30.3	76.38	7.17	2.15	69.4
1981	22.8	18.17	6.07	4.50	65.7
Mean	26.9	79.02	6.36	3.34	68.1

and plants produced stronger branches due to manual flower removal or by spraying 0.3% ethrel and 2% carbamide on the deflowered plants. These treatments resulted in significant improvement in yield and quality of lac. Since pigeonpea flowers store maximum P, their removal from the plants increased P level within the plant system (Kaiwei et al. 1988). The lac insects reared on pigeonpea plants with no flowers and pods not only produced lac of high quality but also more yields. This is a significant observation since at ICRISAT pigeonpea scientists have developed long-duration lines in which the pod setting is inhibited due to the presence of genetic/ cytoplsamic male-sterility systems (Saxena and Kumar 1999). The use of such materials in lac production may help in increasing yield and quality of lac for a longer period without manual removal of the flowers.

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ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 2000. Bringing hope to marginal environments: chickpea improvement at ICRISAT. Patancheru 502 324, Andhra Pradesh, India: ICRISAT. 52 pp. ISBN 92-9066-422-3. Order code GAE 037. Single copy free.

Chickpea is by far the most important leguminous food grain, or pulse, in the diets of the peoples of South Asia. The accomplishments of ICRISAT's partnership-based chickpea research-for-development thrust over the past quarter century are described: over 100 improved chickpea varieties have been released, including a new type of adaptation that has enabled the crop to extend its range far south; resistance to fusarium wilt; integrated control options for botrytis gray mold; enhanced root mass for drought resistance; an understanding of resistance mechanisms against *Helicoverpa* pod borer; and molecular marker and gene transformation techniques to significantly accelerate breeding progress. Chickpea research by ICRISAT and its partners has created a wealth of technical options for increasing productivity in marginal areas for this vital, protein-rich foodstuff of the poor.

Silim, S.N., Mergeai, G., and **Kimani, P.M.** (eds.) 2001. Status and potential of pigeonpea in eastern and southern Africa: proceedings of a regional workshop, 12–15 Sep 2000, Nairobi, Kenya. B-5030 Gembloux, Belgium: Gembloux Agricultural University; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 232 pp. ISBN 92-9066-432-0. Order code CPE 130. LDC $23.00. HDC $61.00. India Rs 825.00.

Pigeonpea is a multipurpose, multi-benefit crop adapted to semi-arid conditions, and an important component of traditional intercropping systems in eastern and southern Africa. A range of improved technologies is available. Workshop participants suggested the following: (i) Consolidate research information into a comprehensive technology inventory for the region, and identify gaps in knowledge; (ii) Identify specific markets, package available technologies (variety, management) for each of these markets, and establish links with marketing agencies where possible; and (iii) Initiate studies to collect additional information, particularly on market opportunities, transaction costs, and comparative advantages.

Publication from PARC

Muhammad Bashir, Zahoor Ahmad, and **Nobuo Murata.** 2000. Seed-borne viruses: detection, identification and control. Islamabad, Pakistan: Pakistan Agricultural Research Council. 156 pp. ISBN 969-409-129-2. Price in Pakistan Rs 200.00; other countries US$ 20.00.

About 90 percent of all food crops are attacked by devastating seed-borne pathogens. The transfer of genetic stock on a global scale, either for utilization or for conservation involves possible risks of widespread distribution of seedborne viruses. Such risks can be minimized by ensuring that imported as well as locally produced seeds are virus-free. The book covers all aspects related to seedborne viruses in seven chapters: characteristics of seedborne viruses; mechanism of seed transmission; seed health testing; serology in virus detection; quarantine and genetic resources; viruses of quarantine significance; and control of seed-borne viruses. More than 300 seed-borne viruses (including chickpea viruses) with their geographical distribution and percent seed transmission have been listed in the book.

The book can be ordered from:

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Chickpea publications

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