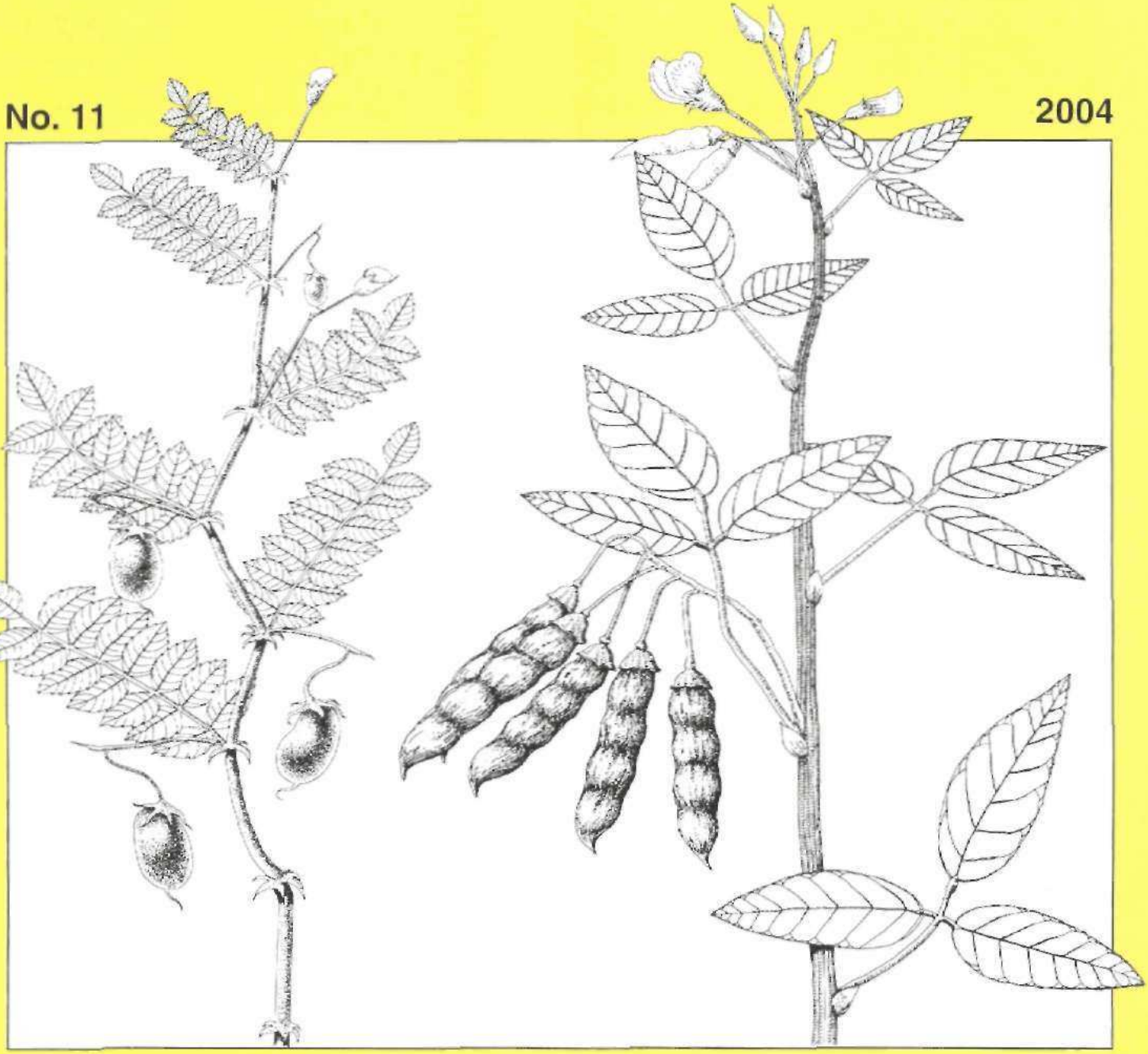
International Chickpea and Pigeonpea Newsletter

No. 11 2004



International Chickpea and Pigeonpea Newsletter

Publishing objectives

The International Chickpea and Pigeonpea Newsletter (ICPN) is published annually by ICR1SAT. 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 (eg, 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 arc 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. 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 should be sent before 31 March to:

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Editorial

I am pleased to present this issue of the International Chickpea and Pigeonpea Newsletter (ICPN) to the scientific community. It is heartening to note that a substantial number of articles in this issue is from developed countries, particularly USA, indicating growing importance of chickpea and pigeonpea. However, the issue still contains most articles from Asia, which really does not reflect the quantum of research being carried out in Africa. Similarly there are only four articles on pigeonpea in this issue; the low number also does not reflect importance of the crop and research carried out. I believe ICPN can be a good informal vehicle to bring the research on chickpea and pigeonpea to wider readership. A large proportion of our research results remains unpublished or is published in vernacular publications, thus depriving a wider section of scientific community, the outcome of scientific efforts. I urge the scientists from Africa and those working on pigeonpea to share their research results with the readership of ICPN.

I request authors to follow ICPN guidelines for length of submission and format. This will greatly reduce time in processing and acceptance of papers for publication in ICPN. We are including the feedback sheet on the newsletters in this issue, and I request readers to respond promptly.

I would like to acknowledge contributions of M Blummel, S Chandra, SL Dwivedi, R Folkertsma, PM Gaur, L Krishnamurthy, N Mallikarjuna, S Pande, RPS Pundir, GV Ranga Rao, LJ Reddy, OP Rupela, KL Sahrawat, KB Saxena, HC Sharma, KK Sharma and RP Thakur as reviewers of contributions to this issue of ICPN, and the Library and Documentation Service at ICRISAT for compiling the SATCRIS listing.

I assure you that with cooperation from the contributors and readers, we will try our best to ensure that ICPN continues to maintain high standards in disseminating information efficiently and effectively among chickpea and pigeonpea workers.

HD Upadhyaya

News

About Scientists

HD Upadhyaya, Special Project Scientist, Genebank, ICRISAT was awarded "Millennium ICRISAT Science Award 2003" as the Outstanding Scientist in recognition of his contribution to reducing poverty, hunger and malnutrition through sustainable increase in productivity and by broadening the genetic base of crops and insuring against vulnerability to diseases and pests.

Om Gupta, Principal Scientist (Plant Pathology) and In-charge of All India Coordinated Research Project (AICRP) on chickpea at the Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKW), Jabalpur, India has been awarded " ISPRD Recognition Award 2003" by the Indian Society of Pulses Research and Development for her outstanding contributions to pulses research leading to integrated management of major diseases. The award was presented by the Union Minister of Agriculture, Shri Rajnath Singh at the National Symposium on Pulses for Crop Diversification and Natural Resource Management organized on 20-22 December 2003 at the Indian Institute of Pulses Research (IIPR), Kanpur, India.

Pulses Activities on the Web

To cater to the needs of all concerned, the Directorate of Pulses Development, Ministry of Agriculture, Government of India, Bhopal, India, the national headquarter for pulses development, has developed and launched a website on countrywide pulses development and activities being undertaken by the Directorate through various programs/activities including the on-going centrally-sponsored schemes/projects. Besides containing the profile, activities and achievements of the Directorate a varied range of information on the National Pulses Development Project (NPDP) and related issues can be accessed from http://www.dpd.mp.nic.in hosted by the National Informatics Centre (NIC), Bhopal.

Contributed by: AK Tiwari, *Director, Directorate of Pulses Development, Bhopal, India*

Second Pigeonpea Workshop held at Nelspruit, South Africa

Pigeonpea is emerging as a potential crop for the semi-arid tropics (SAT) in southern Africa. Particularly, South Africa has keen interest to incorporate pigeonpea in the cropping systems in the degraded and sloping lands to ensure sustainability. Although pigeonpea is not grown commercially in South Africa, scientists consider that it has potential to supplement the maize-based diet of the rural and the urban poor. Preliminary trials in the past five years indicate that pigeonpea survives and produces reasonable yields even in the harsher drought years. Hence, the Mpumalanga Ministry of Agriculture, Conservation and Environment (MACE) considers that pigeonpea has potential as a food crop as well as a source of steady supply of fodder to livestock.

The first pigeonpea workshop in South Africa was organized at Nelspruit on 26 May 2000 and attended by 55 participants. The participants of the workshop decided to form the South Africa Pigeonpea Network (SAPNET) to promote pigeonpea as a crop for food and nutritional security and later on a commercial scale for export.

The second pigeonpea workshop was held at Lowveld Research Unit (LRU), a sub-station under MACE, in Nelspruit during 10-11 April 2003. The LRU staff have been involved in identifying new crops that could be included in the local cropping system. They have been evaluating pigeonpea since 1998 with an objective to promote its production in Nsikzi District of Mpumalanga. The performance of the pigeonpea crop has been outstanding. ICRISAT has been assisting this program from its headquarters in Patancheru, India as well as through regional programs in Kenya, Mozambique and Zimbabwe.

Forty-eight participants from South Africa, Mozambique, Swaziland and ICRISAT attended the workshop. ICRISAT was represented by scientists from India, Kenya, Mozambique and Zimbabwe. The program included presentations on progress made on pigeonpea in different countries followed by a field trip to see pigeonpea trials and demonstration plots at LRU. As a result of final discussions in the workshop, the following recommendations were made:

1. The network should be expanded to include other countries in southern Africa to make it Southern African Pigeonpea Network (SAPNET) in consultation with the country representatives.
2. Organizational aspects of SAPNET such as broader objectives, byelaws, membership, fees, etc should be formalized.
3. A Network Steering Committee should be formed to advise on strategic/business plan of the network.
4. Cherian Mathews will continue as the Coordinator for SAPNET and will formulate pigeonpea developmental programs with members of SAPNET.
5. The broad objectives of SAPNET should include: (i) food security; (ii) soil and water conservation; and (iii) long-term sustainability of smallholder-based cropping systems.
6. The specific activities should include:
   - Enhance efforts to promote utilization of pigeonpea in the local farming communities.
   - Encourage on-farm demonstrations and training on utilization of pigeonpea at many locations.
   - Explore alternative uses of pigeonpea such as fodder, feed, fuel wood, and for soil conservation.
   - Develop technologies for sustainable cropping systems and integrated pest management and disseminate the information to SAPNET members.
   - Establish in-country pigeonpea grain processing facilities through public and private partnership to catalyze utilization and commercialization of pigeonpea.
7. The Instituto Nacional de Investigacao Agronomica (INIA) in Mozambique is establishing a basic seed unit and this could also meet the short-term seed requirements of pigeonpea, as most of the varieties found promising in South Africa are the same identified for release in other African countries (Mozambique, Malawi, Tanzania and Kenya). Therefore, a regional seed multiplication facility would be ideal and would be encouraged by ICRISAT.
8. ICRISAT should include SAPNET and its needs in its regional research and development plans for southern Africa.

Contributed by: RPS Pundir, *Visiting Scientist, Crop Improvement, ICRISAT, Patancheru, India*

Chickpea and Pigeonpea Meetings

Future Research Priorities for Chickpea and Pigeonpea Improvement

CLL Gowda[1], PM Gaur[1], KB Saxena[1], Maxood Ali[2], Muhammad Bashir[3], Azizur Rahman[4], RK Neupane[5], Zong Xuxiao[6], Aung May Than[7], H Samartunga[8], Ketema Daba[9], EJ Knights[10] and **Tom Warkentin[11]** (1. ICRISAT, Patancheru 502 324, Andhra Pradesh, India; 2. Indian Institute of Pulses Research, Kanpur 208 024, India; 3. National Agricultural Research Centre, Islamabad 45500, Pakistan; 4. Pulses Research Centre, lshrudi 6620, Pabna, Bangladesh; 5. National Grain Legumes Research Program, Rampur, Chitwan, Nepal; 6. Chinese Academy of Agricultural Sciences, Beijing 100081, China; 7. Central Agricultural Research Institute, Yezin, Myanmar; 8. Field Crops Research and Development Institute, Maha llluppallama, Sri Lanka; 9. Debre Zeit Agricultural Research Centre, Debre Zeit, Ethiopia; 10. The Tamworth Centre for Crop Improvement, Tamworth, NSW 2340, Australia; 11. University of Saskatchewan, Saskatoon S7N 5A8, Canada)

Chickpea (*Cicer arietinum)* and pigeonpea (*Cajanus cajan)* are important grain legumes for the resource-poor farmers in the semi-arid tropics. More than 95% of the global area under these crops is in the developing countries. The potential grain yield of these crops is 4 to 5 t ha^{-1}, but the global average yield ranges between 0.6 and 0.8 t ha^{-1}. These crops are largely grown rainfed under low-input conditions and their productivity is constrained by various biotic and abiotic factors.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partners [the national programs, advanced research institutes, non-governmental organizations (NGOs), private sector, and farmers] are committed to attain sustainable increases in the productivity potential of these legumes. The research and development priorities at ICRISAT have been dynamic and are guided by the changing scenario of the fanning systems, the needs of the farmers and consumers and the development of improved technologies. The research priorities are revisited periodically through discussions with national program scientists, extension personnel, farmers, consumers and industry, and the feedback received is used in refining or redefining the research priorities for the future.

ICRISAT organized an International Chickpea Scientists' Meet during 16 to 17 January 2003 and an International Pigeonpea Scientists' Meet during 13 to 14 November 2003 at Patancheru, India. Thirty scientists from Australia, Bangladesh, Canada, Ethiopia, India and Nepal and 14 scientists from ICRISAT participated in the Chickpea Scientists' meeting. Fifty scientists, including 12 from ICRISAT, 32 from India, and one each from China, Myanmar, Nepal, Sri Lanka, UK and USA participated in the Pigeonpea Scientists' meeting. The objectives of these meetings were to: (i) visit the research experiments at ICRISAT; (ii) provide opportunity for scientists to select germplasm and breeding material; (iii) exchange information among scientists from various national programs and ICRISAT; and (iv) identify future research thrusts and priorities for research globally.

Representatives from the participating countries presented the current status and future research thrusts for chickpea and pigeonpea in the respective national programs. Major priority areas of research for these crops in different countries are summarized in Table1. Group discussions were subsequently held to prioritize research thrusts across countries. Each scientist gave a scoring or priority, based on the local, national or global importance of the constraints and the need for future research. The chickpea and pigeonpea groups identified the following future research thrusts.

Chickpea

1. Pyramiding of genes for resistance to major insect pests (*Helicoverpa* pod borer) and diseases (ascochyta blight and botrytis gray mold), for which levels of resistance are not high in the cultivated germplasm
2. Incorporation of drought, heat and cold tolerance traits as per needs of the national programs
3. Identification of diverse germplasm sources for important economic traits
4. Development of transgenics for resistance to pod borer, ascochyta blight, botrytis gray mold and chickpea stunt
5. Integrated pest management (IPM), including biological control agents
6. Accessing desirable genes from wild species (through tissue culture, embryo rescue, etc)

Table 1. Major priority areas of chickpea and pigeonpea research in different countries'.

Priority areas for research	Countries
Chickpea	
Tolerance to drought and cold and development of short-duration varieties	India, Pakistan, Bangladesh (except cold tolerance), Nepal, Ethiopia, Australia, Canada
Resistance to *Helicoverpa* pod borer and integrated management	India, Pakistan, Bangladesh, Nepal, Ethiopia, Australia
Resistance to fusarium wilt	India, Pakistan, Bangladesh, Nepal, Ethiopia
Resistance to ascochyta blight and integrated management	India, Pakistan, Ethiopia, Australia, Canada
Resistance to botrytis gray mold and integrated management	India, Bangladesh, Nepal, Australia, Canada
Resistance to phytophthora root rot	Australia
Exploitation of wide crosses, transgenics, and marker-assisted breeding	India, Australia, Canada
Improved seed systems	Ethiopia
Pigeonpea	
Resistance to *Helicoverpa* and *Maruca* pod borers, podfly and bruchids	India, Nepal, China, Myanmar, Sri Lanka
Resistance to fusarium wilt	India, Nepal, Myanmar
Resistance to sterility mosaic	India, Myanmar, China
High fodder yield or dual-purpose varieties	China, India
Integrated pest management	India, Nepal, China, Myanmar
Exploitation of hybrid vigor for yield and stability	India
Exploitation of wide crosses, transgenics and marker-assisted breeding	India

1. Includes countries that were represented in International Chickpea Scientists' Meet, 16-17 January 2003 and International Pigeonpea Scientists' Meet, 13-14 November 2003 organized at ICRISAT, Patancheru, India.

7. Marker-assisted selection to hasten breeding cycles
8. Development of short-duration varieties for escaping drought and fitting the crop in narrow windows in some cropping systems
9. Improved seed systems (seed villages, community seed banks, etc)
10. Integrated water and nutrient (nitrogen, phosphorus, micronutrients, biological nitrogen fixation) management

Pigeonpea

1. Resistance to major insect pests *(Helicoverpa* and *Maruca* pod borers, and podfly) and diseases (fusarium wilt, sterility mosaic, phytophthora blight, alternaria blight and phoma stem canker)
2. Development of IPM strategies for management of the above stresses, including use of biological control and biopesticides
3. Development of transgenics for pod borer

4. Introgression of genes from wild *Cajanus* species
5. Development of dual-purpose (fodder and grain) varieties and hybrids

Conclusions

It is obvious that there are some common high priority areas, while some reflect the local/regional research priorities. For obvious reasons, some of the constraints in certain countries or regions may not have high priority or were not reflected in the global research priorities. These need to be addressed by the local/national programs, as per the need. Even then, the priorities for global research for chickpea and pigeonpea are many. The limitation of resources (both human and financial) may not allow ICRISAT to address all the priority research areas. However, considering that we are all committed to partnerships, ICRISAT will attempt to facilitate research collaboration among interested institutes/scientists, so that major priority areas that are important across major producing countries will be addressed adequately.

Research Reports

Chickpea

Genetics/Breeding

Induction of Morphological Mutants in Chickpea

Samiullah Khan, Mohd. Rafiq Wani, Mehraj-ud-din Bhat and **Kouser Parveen** (Mutation Breeding Laboratory, Department of Botany, Aligarh Muslim University, Aligarh 202 002, Uttar Pradesh, India)

The study was aimed at enhancing the frequency and spectrum of mutations in chickpea (*Cicer arietinum)* through mutagenesis for achieving desired plant characteristics. Uniform and healthy seeds of two varieties of chickpea (Avrodhi and BG 256), presoaked in distilled water for 9 h, were treated with chemical mutagens, 0.1, 0.2, 0.3 and 0.4% of EMS (ethylmethane sulfonate) and 0.01, 0.02, 0.03 and 0.04% of SA (sodium azide) and HZ (hydrazine hydrate) for 6 h. Solutions of all the three chemical mutagens were prepared in phosphate buffer of pH 7. For each treatment three hundred seeds were used. Treated seeds were sown in the field with three replications in a complete randomized block design, with each replication consisting of 100 seeds. Seeds soaked in distilled water were used as controls. Seeds of M_1 plants and control plants of both the varieties were harvested separately and sown in plant progeny rows to raise M_2. A wide range of morphological mutants were isolated in M_2 (Table 1). Mutation frequency was estimated for each mutant in each variety and each treatment as percentage of the total M_2 plants.

The frequency and spectrum of morphological mutants was relatively wide with EMS treatments followed by HZ and SA. The variety Avrodhi gave higher frequency of morphological mutants than BG 256 (Table 1). This reflects differences in their mutagenic sensitivity. The differential spectrum of morphological mutations has been reported in chickpea also by Kharkwal (1999). Most of the mutants, isolated in this study, exhibited negative selection value due to pleiotropic nature of the mutated genes. However, the compact growth mutant may be useful in chickpea breeding as experimental material for understanding the linkage relationships of genes.

Mutations affecting growth habit, flower color and plant type have been reported in chickpea earlier (Ahmad and Godward 1993, Kharkwal 1999, Gaur and Gour 2001). Dwarf mutants occur widely in different plant species. Dwarfness may be due to reduced internode length or internode number or both (Sjodin 1971). In our study reduction in internode length was mainly responsible for dwarfness. A gigas mutant was obtained by Singh (1996) in black gram (*Vigna mungo),* which was vigorous in growth and had bold seeds. In chickpea, gigas mutants had vigorous growth and bold, wrinkled seeds (Table 1). Flower color mutants can be exploited as genetic markers in different breeding experiments (Datta and Sengupta 2002, Atta et al. 2003). Chary and Bhalla (1988) isolated sterile mutants in pigeonpea (*Cajanus cajan*) and reported that the sterility is governed by a single recessive allele and can be used in the development of composite crosses and in evolutionary breeding methods.

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Atta B M, Ahsan ul Haq M, Shah T M, Sadiq M, Mahmud ul Hasan and **Syed H. 2003.** Induced flower colour mutations in chickpea. International Chickpea and Pigeonpea Newsletter 10:6-7.

Chary SN and **Bhalla JK. 1988.** EMS induced male sterile mutant in pigeonpea (*Cajanus cajan* (L.) Millsp.). Indian Journal of Genetics and Plant Breeding 48(3):303-304.

Datta AK and **Sengupta K. 2002.** Induced viable macromutants in coriander (*Coriandrum sativum* L.). Indian Journal of Genetics and Plant Breeding 62(3):273-274.

Gaur PM and **Gour VK. 2001.** A gene inhibiting flower colour in chickpea (*Cicer arietinum* L.). Indian Journal of Genetics and Plant Breeding 61(1):41-44.

Kharkwal MC. 1999. Induced mutations in chickpea *{Cicer arietinum* L.). III. Frequency and spectrum of viable mutations. Indian Journal of Genetics and Plant Breeding 59(4):451-464.

Singh RK. 1996. Gamma ray induced bold seeded mutants in *Vigna mungo* (L.) Hepper. Indian Journal of Genetics and Plant Breeding 56(1): 104-108.

Sjodin J. 1971. Induced morphological variations in *Vicia faba* L. Hereditas 67:155-180.

Table 1. Frequency and spectrum of morphological mutants induced by various chemical mutagens in M_2 generation of chickpea[1].

Mutant type	Characteristics	Variety	EMS Conc (%)	EMS Frequency (%)	SA Conc (%)	SA Frequency (%)	HZ Conc (%)	HZ Frequency (%)	No. of mutants/ total no. of plants	Total frequency (%)
Dwarf	Short internodes, reduced height (26 to 37 cm as compared to average 55 cm in control), reduced yield	Avrodhi	0.2	0.98	–	–	–	–	17/1018	1.66
		BG 256	0.3	0.68	–	–	–	–		
Compact	Reduced height, condensed internodes, densely arranged leaflets	Avrodhi	0.3	0.93	–	–	–	–	14/1007	1.39
		BG 256	0.3	0.46	–	–	–	–		
Prostrate	Creeping on ground, foliage spread 60-75 cm diameter in comparison to 40-45 cm in control plant, small pods containing 2 or 3 shriveled seeds (2 seeds in control), hard and rough seed coat	Avrodhi	0.1	1.64	0.04	1.51	0.01	1.05	46/986	4.66
		BG 256	0.1	0.46	–	–	–	–		
Gigas	Vigorous, upright, tall, with large, thick and closed pinnae, bigger and hairy pods with bold and wrinkled seeds	Avrodhi	–	–	0.03	0.55	–	–	6/1088	0.55
		BG 256	–	–	–	–	–	–		
White flower	White petals, wings and keel	Avrodhi	–	–	–	–	–	–	4/953	0.42
		BG 256	0.2	0.42	–	–	–	–		
Non-flowering/ vegetative mutants	No flowers produced	Avrodhi	0.4	0.92	–	–	0.03	2.03	40/1015	3.94
		BG 256	0.3	0.65	–	–	0.03	0.34		
Sterile (I and II)	Sterile I: Seeds extremely shriveled, dark and non-viable Sterile II: No seeds produced	Avrodhi	0.3	1.11	–	–	0.04	0.49	28/965	2.90
		BG 256	0.3	0.49	–	–	0.04	0.81		

1. EMS = Ethylmethane sulfonate; SA - Sodium azide; HZ = Hydrazine hydrate; Conc = Concentration.

Spectrum and Frequency of Induced Mutations in Chickpea

C Toker and **MI Cagirgan** (Department of Field Crops, Faculty of Agriculture, Akdeniz University, TR-07070 Antalya, Turkey)

Chickpea (*Cicer arietinum)* is generally grown on marginal lands and several biotic and abiotic factors such as drought, heat, salinity, cold, insects and diseases constrain its productivity. Therefore, yield of chickpea has not improved much during the past four decades, despite increased efforts by different breeding approaches. To overcome such stresses restricting yield, genetic variation available in germplasm collections are used in development of resistant varieties. Apart from resistance to a few stresses, desirable sources of multiple resistance have not been found in the collections with the exception of wild species (Singh 1997). Thus, a common and efficient tool to create new desirable genetic variability in chickpea is only mutagenesis (Micke 1988). This investigation was undertaken to identify the response of different kabuli chickpea genotypes to gamma rays and the treatment causing maximum viable mutations.

The materials comprised five kabuli chickpea genotypes: Ispanyol population, FLIP 82-259C (released as Aydin 92), ILC 482 (released as Guney Sarisi 482), Urkutlu landrace and FLIP 83-47C (released as Diyar 95). For each dose, approximately 2000 air-dried seeds were irradiated with 100, 200, 300, 400 and 500 Gy of gamma rays from a ^{60}Co source in the Turkish Atomic

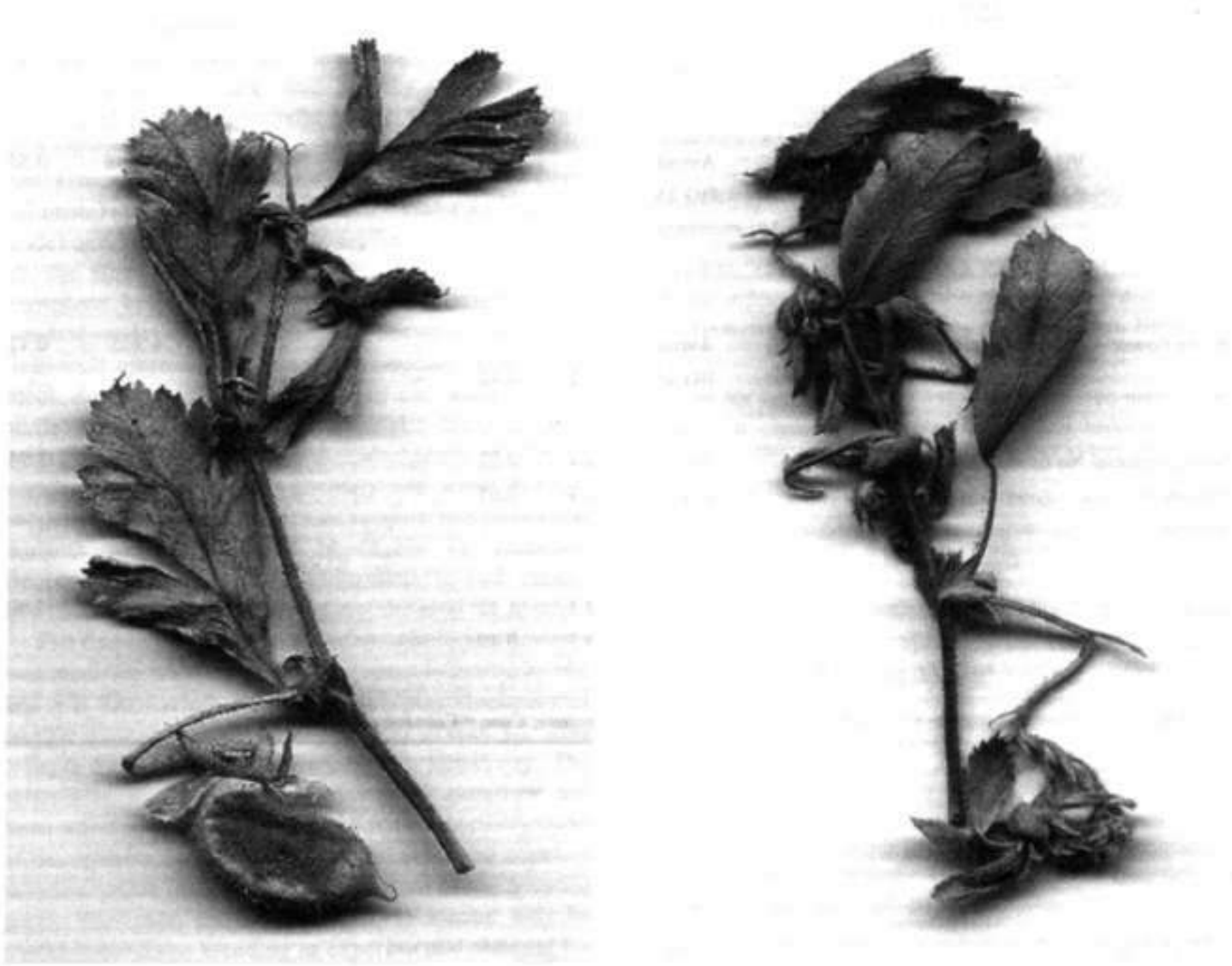

Figure 1. Chickpea mutants: (left) common simple leaf; and (right) a new simple leaf type.

Energy Agency (TAEK), Ankara, Turkey. After irradiation, seeds were stocked at 4℃ until sowing. M_1 plants were grown in field and laboratory conditions. Treated and untreated parents (controls) were grown in pots with eight replications in laboratory conditions in the Faculty of Agriculture, Akdeniz University, Antalya, Turkey to determine the mutagenic effects on seedlings (Sigurbrjonsson 1983). The rest of the treated and control seeds were sown at a spacing of 10 cm in rows of 4 m long and 30 cm apart in the second week of April in 1995 at Urkutlu, Burdur, in the West Mediterranean region of Turkey. Seedling height, germination percentage and days to maturity were recorded to identify the mutagenic effects in M_1 generation. M_1 plants were harvested individually. M_2 generation was raised in separate rows at Urkutlu and sown on 27 March and 3-4 April in 1996. After germination, treated as well as controls were carefully observed for all viable mutations throughout the life period. Mutation frequency was calculated following Kharkwal(1999).

In pot experiment, the first treatment dose (100 Gy) increased seedling height over the control, but increase in the dose of gamma rays resulted in reduction of seedling height (Table 1). Generally, germination was reduced with increasing doses of mutagen under field conditions. However, days to maturity increased with increasing doses of treatment under field conditions (Table 1).

Although plants were observed for dominant mutations and chimeras throughout growing periods, no dominant mutations were identified in M_1 generation. But some

Table 1. Mutagenic effects in M_1 generation of kabuli chickpea genotypes in Turkey.

Genotype	Treatment dose (Gy)	Seedling height[1] (cm)	Germination[2] (%)	Days to maturity[2]
Ispanyol population	0	23.2	NA[3]	116
	100	23.9	12.3	116
	200	19.3	11.3	117
	300	18.4	22.3	118
	400	4.0	17.9	119
	500	2.8	10.0	120
FLIP 82-259C	0	27.8	NA	114
	100	28.0	32.1	115
	200	25.4	31.9	115
	300	23.3	34.6	115
	400	12.3	30.2	115
	500	6.5	25.3	116
ILC 482	0	23.2	NA	106
	100	23.7	46.9	106
	200	20.4	39.2	106
	300	20.2	27.8	107
	400	15.5	33.0	108
	500	15.3	32.9	109
Urkutlu landrace	0	24.2	NA	106
	100	25.7	42.9	106
	200	24.7	41.8	107
	300	22.8	40.5	107
	400	22.0	32.3	108
	500	14.1	25.3	110
FLIP 83-47C	0	26.6	NA	115
	100	27.3	24.4	115
	200	24.7	25.7	115
	300	22.1	28.6	116
	400	18.4	27.3	117
	500	10.5	24.6	119

1. Under controlled conditions in Antalya.
2. Under field conditions at Urkutlu, Burdur.
3. NA = Data not available.

Table 2. Frequency of induced viable mutations in M_2 generations of kabuli chickpea genotypes at Urkutlu, Burdur, Turkey.

Treatment dose (Gy)	No. of M_2 plants[1]					Population size		No. of mutants		Frequency	
	Ispanyol population	FLIP 82-259C	ILC 482	Urkutlu landrace	FLIP 83-47C	M_1 family	M_2 plants	Chloro-phyll	Useful	Mutations/ 100 M_1 family	Mutations/ 1000 M_2 plants
100	3420 (0.56)	6980 (0.52)	11820 (0.23)	7700 (0.14)	5480 (0.13)	3170	35400	56	45	17.6	15.8
200	3200 (0.31)	5860 (0.68)	7060 (0.28)	8000 (0.31)	5320 (0.47)	2994	29440	80	40	20.2	20.5
300	4140 (0.39)	4900 (0.43)	7140 (0.28)	8020 (0.34)	3300 (0.30)	3075	27500	55	39	15.6	17.4
400	2320 (0.56)	3260 (0.71)	6420 (0.41)	6440 (0.42)	3320 (0.48)	2812	21760	67	38	20.0	25.9
500	860 (0.00)	2820 (0.36)	5000 (0.20)	4720 (0.49)	2180 (0.73)	2358	15580	41	18	11.8	17.9
Overall	13940 (0.42)	23820 (0.44)	37440 (0.27)	34880 (0.32)	19600 (0.38)	14409	129680	299	180	17.0	19.5

1. Percentage of mutations is given in parentheses.

chimeras were observed. In M_2 generation, many different mutants were noticed as viable mutations: (i) chlorophyll deficiency mutations (viridis, xantha and albino); (ii) leaf and leaflet mutations (common simple leaf, new simple leaf mutation, narrow leaflets and smooth leaflets in edges); (iii) pod and seed mutations (big and small podded, pea-shaped seeds); (iv) flower mutations (open flower, male and female sterile flowers); (v) phenologic mutations (late and early maturity); and (vi) morphologic mutations (grass like, taller than parents, shorter than parents, pigmented foliage, etc) (Table 2). Mutants with leaf variations have been reported by Muehlbauer and Singh (1987). We observed a new leaftype mutant (Fig. 1).

The following results were concluded from our study. Germination percentage was reduced by increasing doses, especially in large-seeded types in field condition. Seedling height was increased by the first treatment (100 Gy) over the control in controlled condition. Days to maturity were increased with increased doses oftreatment in field condition. The frequency ofchlorophyll mutations in M_1 corresponded to the occurrence of morphological mutants in M_2. Effective dose of mutagen varied from genotype to genotype. Maximum viable mutations were obtained with 200 Gy treatments. Generally 500 Gy dose was excessive for all varieties. FLIP 82-259C produced more mutants than others. Many mutants were induced and one leaf type mutant was selected for the first time. The results suggest that mutation techniques could be effectively used for inducing genetic variations in chickpea.

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Genotypic Variations for Root and Shoot Growth at Seedling Stage in Chickpea Mutants

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Chickpea (*Cicer arietinum)* is traditionally grown as a spring-sown crop in the Mediterranean region including Turkey. Precipitation in the region is insufficient and irregular, especially in spring. During spring, the moisture in the soil and rainfall continuously decline while drought and high temperature stresses consequently increase. Under these circumstances, yield of chickpea was constrained by drought, accompanied with high temperature stress. To escape drought stress, earliness is one of the most important mechanisms in spring-sown crop (Singh et al. 1994). Besides earliness, root characters are important in adaptation to drought environments. However, the study on root traits in chickpea using large number of genotypes (Krishnamurty et al. 2003) has been difficult owing to the time consumed and destructive sampling of plants (Gregory 1988). Maximum extraction of the limited available water in the soil could be achieved only by a deeper root system and early growth vigor in drought-prone environments (Saxena et al. 1993a, Wery et al. 1994). This study was aimed at identifying genotypic variations for root and shoot growth in chickpea mutants during seedling stage.

A total of 45 genotypes, including 36 mutants selected from five parents (Ispanyol population, FLIP 82-259C, ILC 482, Urkutlu landrace and FLIP 83-47C), one drought tolerant genotype (ICC 4958) (Saxena et al. 1993b) and three accessions of two annual wild *Cicer* species (C. *reticulatum* and *C. echinospermum)* were sown in the greenhouse at the Faculty of Agriculture, Akdeniz University, Antalya, Turkey. Plants were

Table 1. Root and shoot growth in mutant chickpea lines and checks in Antalya, Turkey[1].

	Root length (cm)			Shoot height (cm)		
Genotype[2]	1st week	3rd week	5th week	1st week	3rd week	5th week
Mutants						
1300155	9.0 ± 2.0	19.6 ± 1.2	21.2 ± 0.8	4.5 ± 0.5	15.2 ± 0.9	18.4 ± 0.7
2100019	12.3 ±2.3	23.7 ± 1.0	24.7 ± 0.8	7.5 ± 0.5	18.0 ± 1.0	21.0 ± 1.2
2100257	10.4 ± 0.7	22.6 ± 1.1	22.8 ± 1.0	6.0 ± 0.3	15.4 ± 1.0	17.8 ± 1.1
2100287 (xx)	12.0 ± 1.0	23.0 ± 1.0	25.5 ± 0.5	5.0 ± 0.0	16.0 ± 1.0	20.0 ± 2.0
2100287 (X.)	12.0 ± 1.3	24.8 ± 1.3	25.4 ± 1.2	7.9 ± 0.6	21.4 ± 0.9	23.6 ± 0.5
2100324	6.6 ± 1.3	24.6 ± 1.2	27.6 ± 0.8	4.0 ± 0.0	14.3 ± 0.6	18.0 ± 1.0
2200068	12.7 ± 0.6	19.0 ± 2.0	20.6 ± 2.5	6.2 ± 0.4	13.2 ± 1.3	15.8 ± 0.8
2200072	10.8 ± 1.3	26.8 ± 1.0	26.8 ± 1.0	7.2 ± 0.4	17.0 ± 0.4	18.8 ± 0.8
2200210	13.0 ± 2.0	19.7 ± 2.7	20.7 ± 2.5	6.0 ± 0.0	16.7 ± 1.0	19.5 ±1.0
2200214	10.0 ± 0.6	22.2 ± 1.0	22.4 ± 1.1	6.4 ± 0.2	16.4 ± 0.7	19.8 ± 1.2
2200264	12.6 ± 0.3	21.2 ± 1.3	22.5 ± 0.6	7.0 ± 0.0	16.2 ± 0.8	19.0 ± 0.7
2200285	10.5 ±0.8	22.2 ± 1.8	22.8 ± 1.6	6.5 ± 0.6	19.4 ± 0.6	23.8 ± 0.9
2200286	11.4 ± 1.1	21.0 ± 1.3	22.0 ± 1.3	7.6 ± 0.2	17.0 ± 0.4	19.4 ± 0.2
2300011	11.0 ± 0.5	24.5 ± 2.2	24.5 ± 2.2	5.5 ± 0.6	16.5 ± 0.5	19.7 ± 0.2
2300078	8.2 ± 0.7	20.5 ± 1.0	21.7 ± 1.5	5.7 ± 0.4	15.0 ± 1.1	19.7 ± 1.0
2300109	12.0 ± 1.1	20.8 ± 0.8	22.4 ± 0.5	7.6 ± 0.4	18.2 ± 0.4	21.0 ± 0.4
2300161	10.0 ± 1.2	19.8 ± 0.5	20.6 ± 0.5	7.2 ± 0.3	18.0 ± 0.8	20.4 ± 0.9
2300177	6.6 ± 1.2	21.7 ± 0.8	22.5 ± 0.8	5.0 ± 0.5	18.0 ± 1.2	21.5 ±0.6
2300232	11.0 ± 0.0	22.0 ± 0.0	22.0 ± 0.0	5.0 ± 0.0	17.0 ± 0.0	23.0 ± 0.0
2400104	10.5 ± 1.9	22.2 ± 3.0	22.7 ± 2.9	6.0 ± 0.9	16.0 ± 1.0	19.0 ± 0.8
2400106	9.7 ± 0.7	20.7 ± 2.5	21.2 ± 2.2	7.0 ± 0.4	19.7 ± 1.0	21.7 ± 0.4
2400107	9.0 ± 1.6	20.8 ± 1.6	21.6 ± 1.1	4.7 ± 0.4	16.0 ± 0.4	20.6 ± 0.9
2400126	12.0 ± 1.6	18.8 ± 1.1	20.6 ± 0.8	6.2 ± 0.3	22.4 ± 0.6	23.0 ± 0.7
2400157	13.0 ± 1.0	20.7 ± 1.4	21.5 ± 1.3	6.7 ± 0.4	19.5 ± 0.6	20.5 ± 0.6
2500039	10.0 ± 2.0	20.6 ± 1.3	21.6 ± 1.3	5.5 ± 1.5	18.6 ± 0.9	20.6 ± 0.9

continued

Table 1. ***continued***

Genotype[2]	Root length (cm)			Shoot height (cm)		
	1st week	3rd week	5th week	1st week	3rd week	5th week
3100008	12.0 ± 1.0	18.7 ± 1.2	19.5 ± 0.8	6.3 ± 0.3	15.0 ± 0.9	16.7 ± 1.3
3100388	11.6 ± 0.3	20.8 ± 2.8	21.4 ± 2.8	5.6 ± 0.3	17.8 ± 2.1	18.0 ± 0.8
3200117 (X.)	9.0 ± 1.0	19.0 ± 1.7	19.6 ± 2.0	6.0 ± 0.0	15.3 ± 0.3	17.0 ± 0.5
3200891	7.0 ± 1.5	18.4 ± 1.2	19.8 ± 1.0	6.5 ± 0.5	15.4 ± 0.5	16.6 ± 0.4
3400215	10.0 ± 0.0	18.2 ± 0.7	18.5 ± 0.8	6.0 ± 0.5	16.0 ± 0.5	17.7 ± 0.4
5200132	8.0 ± 0.0	18.0 ± 3.6	19.6 ± 2.0	7.0[3]	15.0 ± 1.1	16.0 ± 1.0
Checks						
Ispanyol population	14.0 ± 1.1	26.5 ± 1.5	27.0 ± 1.0	6.0 ± 2.0	20.5 ± 0.5	22.0 ± 1.0
FLIP 82-259C (Aydin 92)	11.5 ± 0.0	22.6 ± 2.3	23.2 ± 2.2	8.0 ± 0.7	16.6 ± 1.6	18.2 ± 1.5
FLIP 83-47C (Diyar 95)	8.0 ± 0.5	15.0 ± 2.8	16.0 ± 2.8	6.0[3]	12.6 ± 0.6	15.3 ± 1.8
Cicer echinospermum (AWC 307)	12.5 ± 2.7	17.0 ± 3.0	19.0 ± 2.3	6.5 ± 3.5	13.0 ± 1.7	15.3 ± 0.8
C. reticulatum (AWC 609)	16.2 ± 1.3	23.4 ± 2.8	23.6 ± 2.6	6.5 ± 0.6	18.2 ± 1.4	20.8 ± 1.9
C. reticulatum (AWC 605)	13.2 ± 0.0	19.6 ± 1.9	20.0 ± 1.8	4.9 ± 0.9	17.8 ± 1.7	19.0 ± 1.5
ICC 4958	11.0 ± 0.0	15.3 ± 1.4	16.6 ± 0.8	5.0 ± 0.0	12.3 ± 2.9	17.3 ± 1.7
F values	**	*	**	**	**	**

1. Data are means ± SE of five replications.
   * = Significant at 5% level; ** = Significant at 1% level.
2. X. is segregated for selected traits and xx is mutant.
3. SE not obtained.

irrigated (at 0.4 L h^{-1}) with fogy system. The materials were grown with five replications at average maximum and minimum temperatures of 31.8°C and 20.2°C, respectively in September and October 2001. Genotypes were grown in plastic boxes of 37 cm length, 52 cm width and 30 cm depth, filled with perlite + coconut peat (1:3 w/w) with EC of 250-500 Micro S cm^{-1}, pH 6.1, total organic matter 96%, 0.5% nitrogen, 2.8% K_2O and 2.8% P_2O_5. Screening was repeated at 7-day intervals. For each genotype, root length and shoot height were recorded.

Genotypic effects were statistically significant for 1st, 3rd, 4th and 5th weeks ($P<0.05$). Five mutants (2100245, 2100282, 2400054, 2500094 and 3200089) and two checks (ILC 482 and Urkutlu landrace) did not germinate. Root length of genotypes ranged from 16 cm to 27.6 cm in 5th week during seedling stage (Table 1). Ispanyol population that has the largest seeds had the highest root length (27 cm) among checks. Among annual wild *Cicer* species, *C. reticulatum* accession AWC 609 had the highest root length of 23.6 cm. Similar results were reported for annual wild *Cicer* species by Krishnamurty et al. (2003). Some mutants, 2100287 (xx), 2100287 (X.), 2100324,2200072, selected from FLIP 82-259C had the longest roots. Mutant 2100324 had the deepest roots (27.6 cm). Shoot height of some mutants, 2100287 (X.), 2200285, 2300232 and 2400126, were higher than parents, ICC 4958 and annual wild *Cicer* species. Similar mutants were also selected from FLIP 82-259C. These results suggest that there is a great deal of variation for root and shoot growth characters in chickpea mutants.

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Preliminary Screening for Nodulation in Chickpea Mutants

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Like several other legumes, chickpea (*Cicer arietinum)* can also meet much of nitrogen (N) demand by N_2 fixation. The amount of N_2 fixed by chickpea under various cropping systems and environmental conditions ranges from 1 to 141 kg ha^{-1} (Rupela and Saxena 1987, Stanforth et al. 1994). Two approaches have been reported for improving legume N_2 fixation: (1) management of the legume crop to minimize stresses and maximize yield; and (2) breeding rhizobia and legume combination with enhanced capacity for N_2 fixation. To breed rhizobia and legume combination with enhanced capacity for N_2 fixation in chickpea, one of the most known approaches is increase the number and effectiveness of rhizobia in the rooting zone through selection (Herridge et al. 1994). This study was aimed to screen and select for nodule number in mutant chickpea lines by comparing with parents and checks in early vegetative stage.

Treatment procedures and growing of M_1 and M_2 generations given in the previous study were followed (Toker and Cagirgan 2004). A total of 45 genotypes, including 36 mutants selected from five parents (Ispanyol population, FLIP 82-259C, ILC 482, Urkutlu landrace and FLIP 83-47C), one drought tolerant genotype (ICC 4958) (Saxena et al. 1993) and three accessions of annual wild *Cicer* species (two accessions from C. *reitculatum* and one accession from *C. echinospermum*) were grown in the greenhouse in Antalya, Turkey. The materials were sown on 4 September 2001 with five replications at average maximum and minimum temperatures of 31.8°C and 20.2°C, respectively. Plants were irrigated (at 0.4 L h^{-1}) with fogy system. Genotypes were grown in plastic boxes

Table 1. Number of nodules per plant in mutant chickpeas and checks grown in the greenhouse in Antalya, Turkey[1].

Genotype	Mean ± SE
Mutants	
1300155	21 ± 3.29
2100019	38 ± 2.26
2100245	8 ± 1.33
2100257	45 ± 3.15
2100287 (xx)	31 ± 2.03
2100287 (X.)	41 ± 3.45
2100282	32 ± 0.33
2100324	20 ± 3.62
2200068	19 ± 2.81
2200072	42 ± 2.41
2200210	28 ± 4.34
2200214	26 ± 3.15
2200264	35 ± 0.48
2200285	41 ± 2.79
2200286	38 ± 2.35
2300011	27 ± 3.30
2300078	30 ± 2.22
2300109	39 ± 1.38
2300161	34 ± 1.07
2300177	28 ± 1.47
2300232	44 ± 0.00
2400054	-
2400104	34 ± 1.91
2400106	46 ± 2.32
2400107	22 ± 0.96
2400126	22 ± 0.83
2400157	35 ± 0.86
2500039	25 ± 2.12
2500094	18 ± 4.04
3100008	32 ± 2.34
3100388	30 ± 2.83
3200089	35 ± 1.73
3200117 (X.)	41 ± 5.46
3200891	41 ± 3.71
3400215	37 ± 2.55
5200132	15 ± 1.68
Checks	
Ispanyol population	20 ± 0.47
FLIP 82-259C (Aydin 92)	22 ± 2.06
ILC 482 (Guney Sarisi 482)	-
Urkutlu landrace	-
FLIP 83-47C (Diyar 95)	14 ± 0.71
Cicer echinospermum (AWC 307)	10 ± 1.82
C. reticulatum (AWC 609)	17 ± 1.63
C. reticulatum (AWC 605)	16 ± 2.46
ICC 4958	12 ± 2.49
F values	
Harvest date	1.28 NS
Genotype	11.03 **
Genotype x harvest date interaction	0.08 NS

1. X. is segregated for selected traits and xx is mutant. Data are means of five samples at four harvest dates. - = Data not obtained; NS = Not significant at 1% level; ** = Significant at 1% level.

of 37 cm length, 52 cm width and 30 cm depth, filled with perlite + coconut peat (1:3 w/w) with EC of 250-500 Micro S cm^{-1}, pH 6.1, total organic matter 96%, 0.5% nitrogen, 2.8% K_2O and 2.8% P_2O_5. The strain of *Bradyrhizobium* sp (*Cicer),* provided by the Research Center for Soil and Water, Ankara, Turkey and also, native strains that were collected the previous year were used (as mixture) as seed coat at sowing. Harvesting for nodulation observations was done at 7-day intervals (14, 21, 28 and 35 days after sowing). For each genotype, number of nodules were recorded in five samples and analyzed using MINITAB statistical program.

Differences among genotypes ($P<0.01$) were statistically significant at all the four harvest dates. However, genotype by harvest interactions were not statistically different ($P<0.05$). Mean number of nodules in mutants (at all four harvest dates) ranged from 8 in mutant 2100245 to 45 in mutant 2100257 (Table1). Some mutants had more than 40 nodules [2100257, 2100287 (X.), 2200072,2200285,2300232,2400106,3200117 (X.) and 3200891]. Young swollen nodule of chickpea could be seen in the second week. These results will be used in future breeding programs aimed at enhancing N_2 fixation in chickpea cultivars.

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Selection of Chickpea Mutants for Cold Tolerance and Ascochyta Blight Resistance

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Chickpea (*Cicer arietinum*) is traditionally sown at the end of spring rains to escape from ascochyta blight, caused by *Ascochyta rabiei,* in the Mediterranean countries, including Turkey. Besides ascochyta blight epidemics, the crop is subjected to drought and high temperature stresses and consequently the yield declines in spring-sown chickpea. However, autumn-sown chickpea produces higher yield than traditionally spring-sown crop, as it could use winter rainfall (Singh et al. 1997). Nevertheless, ascochyta blight has been observed as the major problem in the new production system, and therefore winter-sown chickpea must possess resistance to ascochyta blight as well as cold tolerance (Singh et al. 1989, Singh et al. 1997). This study was aimed to select cold tolerant mutant lines of chickpea with ascochyta blight resistance, suitable for growing in winter in the medium altitudes of the West Mediterranean region of Turkey.

Treatment procedures and growing of M_1 and M_2 generations given in the previous study were followed (Toker and Cagirgan 2004). In M_2 generation, all morphologically deviating plants in each sub-population were tagged and selected at harvest and threshed individually as potential mutants. These materials were sown on 31 October 1996 by hand in M_3 generation as M_2 plant progenies to screen for cold tolerance. The row spacing was 40 cm and seed was sown 10 cm apart in 1-m long rows. The M_3 nursery was irrigated for vegetative growth before the onset of severe winter for cold tolerance screening. ILC 195, ILC 482, ILC 3279 and Canitez 87 were used for comparison as controls together with the parents (Ispanyol population, FLIP 82-259C, ILC 482, Urkutlu landrace and FLIP 83-47C). To evaluate the test materials for cold tolerance, a 1-9 scale (1 = free from damage and 9 = killed due to cold) was used as suggested by Singh et al. (1989). Also, a 1-9 scale (1 = immune and 9 = highly susceptible) was used for reaction to ascochyta blight (Singh and Reddy 1991).

The procedure used for selection for cold tolerance and ascochyta blight resistance in different generations is described.

Table 1. Cold tolerance (CT) and resistance to ascochyta blight (AB) of kabuli chickpea mutants in M_3 generation and checks at Urkutlu, Burdur, Turkey, 1996797.

Genotype	CT[1]	AB[2]	Genotype	CT[1]	AB[2]	Genotype	CT[1]	AB[2]	Genotype	CT[1]	AB[2]
Mutants[3]											
1100021	7	5	2100287 (xx)	6	4	2400126	6	4	3500172	9	-
1100048	9	-	2100287 (x.)	5	4	2400157	5	3	3500223	9	_
1100051	9	-	2100324 (x.)	7	4	2400161	9	-	4100159	9	-
1100062	9	-	2100324 (xx)	5	4	2400163	9	-	4200035	9	-
1100090	9	-	2100346	7	4	2500005	9	_	4200230	4	4
1100153	7	4	2200053	9	-	2500031	9	-	4200302	6	4
1200014	8	4	2200064	7	3	2500039	6	3	4300042	9	-
1200065	9	-	2200072	8	4	2500078	8	3	4300068	9	-
1300052	9	-	2200080	9	-	2500094	7	3	4300132	9	-
1300066	9	-	2200089	9	-	3100008	8	4	4300162	9	-
1300085	9	-	2200158	7	3	3100049	9	-	4400086	9	-
1300099	9	-	2200210	4	3	3100161	9	-	4400118	6	8
1300110	9	-	2200214	7	4	3100199	9	-	4400244	9	-
1300133	9	-	2200264 (xx)	7	3	3100388 (xx)	9	-	4400255	9	-
1300155	7	4	2200264 (x.)	6	3	3100388 (x.)	8	4	4500001	9	-
1300161	8	4	2200285	8	3	3100393	9	4	4500236	9	-
1300183	9	-	2200286	4	4	3200089	7	4	5200132	4	4
1400031	9	-	2200287	9	-	3200094	9	-	5200200	9	-
1400110	9	-	2200288	9	-	3200117	5	3	5200266	9	-
2100006	9	-	2300011 (xx)	4	3	3200260	9	-	5300115	9	-
2100019	7	3	2300011 (x.)	7	3	3300172	9	_	5300150	9	-
2100056	7	4	2300027	9	-	3300229	9	-	5400084	9	-
2100086	9	-	2300078	6	3	3300279	9	-	5400161	9	-
2100113	9	-	2300109	6	4	3300336	9	-	5500028	9	-
2100122	7	3	2300129	7	3	3400056	9	-	5500049	9	-
2100137	9	-	2300161	7	3	3400071	9	-	5500101	9	-
2100216	9	-	2300167	8	4	3400094	9	-	5500109	9	-
2100243	9	-	2300177	6	3	3400123	9	-	**Checks**		
2100245	8	4	2300190	9	-	3400141	9	-	Ispanyol population	8	7
2100251	9	-	2300210	9	-	3400152	9	-	FLIP 82-259C	6	4
2100253	7	4	2300232	6	4	3400162	9	-	ILC 482	8	5
2100254	9	-	2400012	6	3	3400209	9	-	Urkutlu landrace	8	9
2100257	8	4	2400054	7	3	3400215	6	4	FLIP 83-47C	7	4
2100262	8	4	2400084	9	-	3400248	6	4	ILC 195	8	3
2100269	9	-	2400104 (xx)	9	-	3400288	5	5	ILC 3279	8	3
2100276	8	4	2400104 (x.)	6	4	3400294	9	-	Canitez 87	8	8
2100282	8	5	2400106	4	3	3500016	4	4			
2100286	9	-	2400107	4	4	3500139	9	-			

1. Scored on 1-9 scale where 1 = free from damage and 9 = killed due to cold.
2. Scored on 1-9 scale where 1 = immune and 9 - highly susceptible. - = Killed due to cold and then data not available.
3. x. is segregated for selected traits and xx is mutant.

M_1 (1995):

- Selection of materials for irradiation (ILC 482, FLIP 82-259C and FLIP 83-47C are resistant to ascochyta blight, but Ispanyol and Urkutlu landrace possess specific adaptation trait)
- Selection of doses (100, 200, 300, 400 and 500 Gy of gamma rays)
- Irradiation and growing M_1 with parents as control in April 1995
- Harvesting M_1 as single plant

M_2 (1996):

- Growing M_2 in spring with parents and checks and free from the target stresses
- Selecting all deviating types in any recordable characters as potential mutant

M_3(1996):

- Screening for cold tolerance after winter and screening for resistance to ascochyta blight prior to podding stage in M_3, sown in early autumn with the respective parents and checks
- Including susceptible checks in the nursery for both stresses
- Scoring the reaction of mutants after the susceptible checks were killed
- Reconfirming the resistant mutants in the following generations

The number of days with freezing temperatures in October, November, December, January, February and March were recorded as 3, 0, 4,17, 20 and 18, respectively. The lowest temperature in the middle of February in 1997 was -12.1°C. While susceptible mutants were generally killed due to cold damage, the mutants 2200210, 2200286, 2300011, 2400106, 2400107, 3500016, 4200230 and 5200132 were identified as cold tolerant (Table 1). The cold tolerant lines were also resistant to ascochyta blight under field conditions. Besides morphologically different types, tall, erect and late-maturing types were especially selected, since most of the lines that showed resistance to ascochyta blight had these traits (Singh and Reddy 1991). Similarly, Haq and Singh (1994) designed a mutation-breeding program and successfully selected a cold tolerant and ascochyta blight resistant line, M 16119, for the first time. This mutant was also very late-maturing type. Our results have clearly suggested that mutation techniques can be effectively used in inducing complex traits that inherited quantitatively such as cold tolerance and ascochyta blight in chickpea.

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JGK 1: A New Large-seeded, Short-duration, High-yielding Kabuli Chickpea Variety for Central India

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India accounts for over 60% of global chickpea (*Cicer arietinum*) production and more than half of it comes from the Central Zone (CZ) that includes the states of Madhya Pradesh, Maharashtra and Gujarat and small portions of Rajasthan, Uttar Pradesh, Chhattisgarh and Andhra Pradesh. The chickpea cultivars grown in the CZ are predominantly desi type. The increasing demand of kabuli chickpea in the market and availability of short-duration kabuli chickpea varieties have attracted farmers of the CZ to grow kabuli chickpea in recent years. Kabuli chickpea fetches 50 to 100% higher price than desi types depending on seed size. There is now an increasing preference for large-seeded (100-seed mass>30 g) kabuli

chickpeas in India. Until recently, no kabuli chickpea variety having large seed size (100-seed mass>25 g) was available in the CZ. Thus, in kabuli chickpea breeding the major emphasis has been on development of large-seeded, short-duration varieties. The first large-seeded kabuli chickpea variety released for the CZ is PKV Kabuli 2 (KAK 2) in 2000 (Zope et al. 2002). This report describes another such variety released recently as JGK 1 (Jawahar Gram Kabuli 1).

JGK 1 was derived from a three-way cross [(ICCV 2 x Surutato 77) x ICC 7344] made at ICRISAT, Patancheru, India during the 1987/88 season. Among parents, ICCV 2 is an extra-early (85-90 days), medium-seeded (100-seed mass 25 g), high-yielding popular kabuli variety, which is resistant to fusarium wilt and is grown widely in southern and central India, Myanmar and Sudan. Surutato 77 and ICC 7344 (Angostura) are extra large-seeded (100-seed mass >50 g) kabuli germplasm lines from Mexico.

JGK 1 was entered as JKG 92337 by the Jawaharlal Nehru Agricultural University, Jabalpur, Madhya Pradesh in the trials of All India Coordinated Research Project on Chickpea (AICRPC) and tested in the CZ for three years - Initial Varietal Trial (IVT) 1999-2000, Advanced Varietal Trial-1 (AVT-1) 2000-01 and Advanced Varietal Trial-II (AVT-II) 2001-02. On an average, it gave 9.5% higher yield over the check L 550, 20.0% over ICCV 2, 13.6% over BG 1003 and 31.6% over KAK 2 (Table 1). JKG 92337 has large (100-sced mass 31.8 g) and attractive seeds (Fig. 1 and Table1).

JKG 92337 is a short-duration variety maturing in 109 to 119 days, with an average of 114 days (Table1). Short-duration chickpea varieties are needed in the CZ as the crop is generally grown under rainfed condition on residual moisture and the long-duration varieties circumvent to terminal drought. On an average, JKG 92337 took only 5 days more than ICCV 2 to mature. It matured 10 days earlier than L 550, 2 days earlier than BG 1003 and 5 days earlier than KAK 2.

Fusarium wilt is one of the most important diseases of chickpea in the CZ. JKG 92337 was tested along with checks L 550, BG 1003 and KAK 2 for resistance to this disease at 13 locations during 2000/01 and at 9 locations during 2001/02 under pathological trials of AICRPC. Though none of the varieties was resistant at all the locations, JKG 92337 was found resistant (<20% mortality) at more number of locations as compared to other varieties during 2000/01 (Table 1). However, during 2001/02 season all varieties had similar wilt reaction.

Pod borer *(Helicoverpa* sp) is the most important insect pest of chickpea. JKG 92337 was tested along with the checks L 550, BG 1003 and KAK 2 for resistance to pod borer at 6 locations during 2000/01 and at 4 locations during 2001/02 in entomological trials of AICRPC. On an average, only 13.8% pods were damaged in JKG 92337 as compared to 15.7 to 18.3% in other varieties (Table1).

Based on its superior performance over KAK 2, JKG 92337 was identified for release in CZ by the Variety Identification Committee during the Annual Group Meet of AICRPC held at CCS Haryana Agricultural University, Hisar, India during September 2002. It was later released and notified by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops in its meeting held on 13 December 2002. The variety has been registered with the National Bureau of Plant Genetic Resources, New Delhi, India under the number IC 296329.

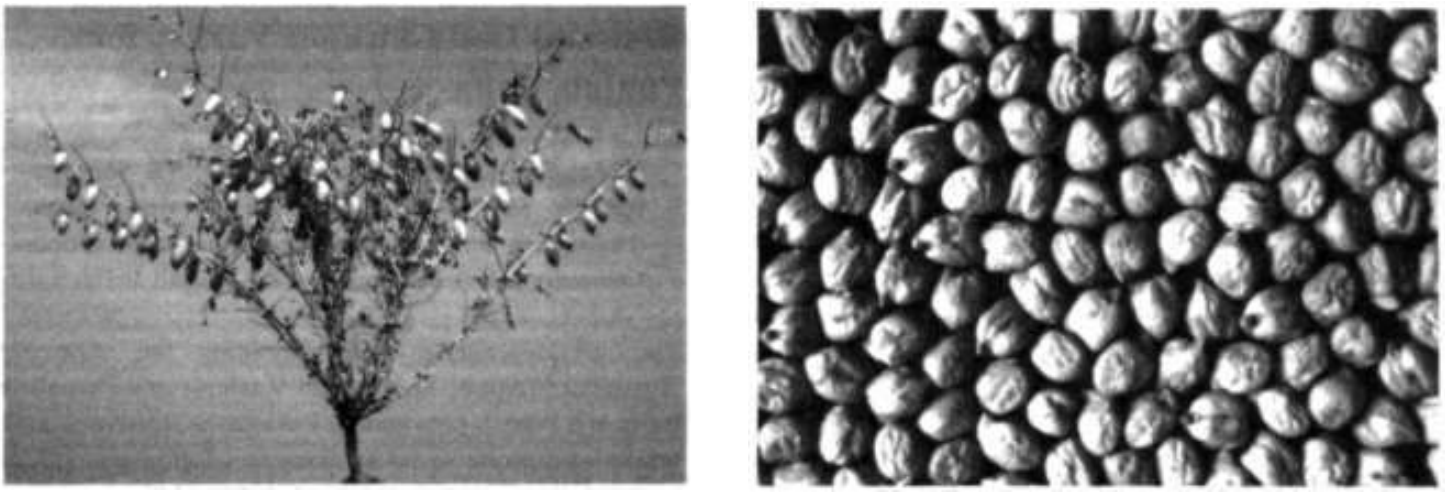

Figure 1. Kabuli chickpea variety JGK 1 (JKG 92337) released in central India: (left) a typical plant; and (right) large seeds.

Table 1. Yield performance and other characteristics of JKG 92337 (JGK 1) in comparison to check varieties in various All India Coordinated Trials conducted in the Central Zone of India during 1999-2002.

Trials[1]	JKG 92337	L 550	ICCV 2	BG 1003	KAK 2
Yield (kg ha^{-1})					
IVT 1999-2000	1918 (6)[2]	1668 (5)	1597(6)	1769(6)	-
AVT-1 2000-01	1518(6)	1353(5)	-	1294 (6)	1192 (6)
AVT-II 2001-02	1502(5)	-	1118(5)	1275 (5)	1335 (5)
Weighted average	1655	1511	1379	1456	1257
Increase (%) in yield of JKG 92337 over check	-	9.5	20.0	13.6	31.6
100-seed mass (g)					
IVT 1999-2000	28.7 (6)	19.8 (6)	23.5 (6)	24.4 (6)	-
AVT-I 2000-01	32.7 (6)	20.4 (5)	-	24.0 (6)	35.3 (6)
AVT-II 2001-02	34.0 (6)	-	21.6(6)	22.3 (6)	36.4 (6)
Weighted average	31.8	20.1	22.6	23.6	35.8
Maturity duration (days)					
IVT 1999-2000	109 (6)	123 (5)	104 (6)	118(6)	-
AVT-I 2000-01	119(6)	125 (5)	-	108 (6)	120(6)
AVT-II 2001-02	115(6)	-	114(6)	122(6)	117(6)
Weighted average	114	124	109	116	119
Fusarium wilt resistance at locations[3] (number)					
AVT-I 2000-01	8(13)	2(13)	-	4(13)	5(12)
AVT-II 2001-02	2(9)	_	-	2(9)	3(9)
Total	10 (22)	2(13)	-	6(16)	8(21)
Pod damage (%) due to pod borer					
AVT-I 2000-01	14.8 (6)	17.6(6)	-	17.0(6)	21.0(6)
AVT-II 2001-02	12.3(4)	15.3(4)	-	13.7(4)	14.3 (4)
Weighted average	13.8	16.7	-	15.7	18.3

1. IVT = Initial Varietal Trial; AVT = Advanced Varietal Trial.
2. Figures in parentheses indicate number of locations tested.
3. Number of locations where the variety was resistant or moderately resistant (<20% plant mortality).

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PBG 5: A New Multiple Disease Resistant Desi Chickpea Variety for Punjab, India

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The sub-montaneous tract adjoining the states of Himachal Pradesh, Jammu and Kashmir and Punjab in India and Punjab province in Pakistan is relatively more humid and prone to foliar diseases of chickpea (*Cicer arietinum*), particularly ascochyta blight (AB) (*Ascochyta rabiei*) and botrytis gray mold (*Botrytis cinerea*).

Table 1. Performance of chickpea cultivars PBG 5 and PBG 1 in various trials from 1990/91 to 2001/02, Punjab, India.

Trials	No. of trials	Yield (kg ha^{-1})		Increase (%) in yield over check PBG 1
		PBG 5	PBG 1	
Research Trials				
Varietial trials	15	1918	1591	20.6
Agronomic trials	2	2152	2136	0.7
Adaptive Trials				
Farm Advisory Services	17	1566	1508	3.8
Departmant of Agriculture, Punjab	8	1513	1512	0.0
Overall mean		1710	1568	9.0

Table 2. Ancillary characters of chickpea varieties PBG 5 and PBG 1[1].

Character	PBG 5	PBG 1 (check)
Plant height (cm)	57	48
Days to 50% flowering	112	106
Days to maturity	164	160
No. of pods plant^{-1}	37	33
100 - seed mass (g)	18	13
No. of seeds pod^{-1}	1.85	1.92
Seed color	Dark brown	Yellowish brown

1. Data are means of four years.

This tract comprising of districts Amritsar, Gurdaspur, Hoshiarpur, Nawanshehar and Ropar, generally has heavy soils and primarily grows rice (*Oryza sativa)* in *kharif* (rainy) season. The farmers grow chickpea crop (generally cultivar PBG 1) after rice harvest. PBG 1 is an AB resistant variety which yields well. However, due to its weak stem, it is prone to lodging in the heavy soils which results in yield losses. Therefore, efforts were made at the Punjab Agricultural University (PAU), Ludhiana, Punjab, India to develop a desi chickpea variety which possesses multiple resistance to diseases and tolerance to lodging. One such variety, PBG 5, was

Table 3. Reaction of chickpea varieties PBG 5 and PBG 1 to different diseases in Punjab, India.

Year	Location	Ascochyta blight[1]		Fusarium wilt[2] (%)		Foot rot[2] (%)		Dry root rot[2] (%)	
		PBG 5	PBG 1	PBG 5	PBG 1	PBG 5	PBG 1	PBG 5	PBG 1
1990/91	Ludhiana	3.0	5.0	3.1	4.7	3.1	10.5	3.1	3.2
1991/92	Ludhiana	3.8	5.5	5.8	6.2	4.2	6.2	4.2	6.8
1992/93	Ludhiana	3.5	4.8	15.6	17.9	8.9	7.3	6.7	5.7
1993/94	Ludhiana	3.0	3.2	9.8	7.2	7.2	9.0	6.9	6.0
1993/94	Gurdaspur	3.1	4.0	–	–	–	–	–	–
1994/95	Ludhiana	3.0	3.0	13.0	13.4	8.0	9.1	5.0	4.9
1995/96	Ludhiana	3.0	4.5	5.9	16.2	3.8	16.4	3.8	9.0
1996/97	Ludhiana	3.0	3.0	-	-	-	-	-	-
1997/98	Ludhiana	5.0	6.0	1.3	33.6	0.0	13.3	0.0	6.2
1998/99	Ludhiana	3.2	3.5	4.0	55.7	2.0	11.6	0.0	11.5
1999/2000	Ludhiana	3.0	3.5	7.0	0.0	7.0	7.0	8.3	3.2
2000/01	Ludhiana	2.0	3.5	1.6	11.2	0.0	3.7	1.6	6.2
Overall mean		3.2	4.1	6.7	16.6	4.4	9.4	3.9	6.3

1. Disease rating on 1-9 scale (1 = resistant and 9 = highly susceptible) under artificial conditions.
2. Screening in wilt sick plot.
3. - = Not tested.

developed from the cross BG 257 x E 100Y through pedigree method. The female parent BG 257 is a high-yielding genotype while male parent E 100Y possesses resistance to AB and has sturdy stem.

The yield performance of PBG 5 in different varietal trials, agronomic trials and adaptive trials conducted in Punjab, India from 1990/91 to 2001/02 is given in Table 1. In 42 trials, the average seed yield of PBG 5 was 1710 kg ha^{-1} as compared to 1568 kg ha^{-1} of check cultivar PBG 1, with a yield superiority of 9.0%. On an average, PBG 5 possessed 37 pods $plant^{-1}$ and had 100-seed mass of 18 g (Table 2). These are the major yield contributing traits of PBG 5. PBG 5 has erect growth habit and strong stem. Thus, it is less prone to lodging under heavy soil conditions and erect growth allows good aeration in plant canopy. Furthermore, PBG 5 has medium-sized seeds and thus will be preferred by traders as well as consumers.

The reaction of PBG 5 and check cultivar PBG 1 to different diseases in various trials conducted from 1990/91 to 2000/01 is given in Table 3. The average rating of AB in PBG 5 was 3.2 (on 1-9 rating scale where 1 = resistant and 9 = highly susceptible) compared to 4.1 in check cultivar PBG 1. The average incidences of fusarium wilt *(Fusarium oxysporum* f sp *ciceris),* foot rot *(Operculella padwickii)* and dry root rot *(Rhizoctonia bataticola)* in wilt sick plot were 6.7%, 4.4% and 3.9% in PBG 5 compared to 16.6%, 9.4% and 6.3% in PBG 1, respectively.

The new variety PBG 5 has been released by the State Varietal Approval Committee in its meeting held on 11 February 2003 at PAU, Ludhiana for its stable and multiple resistance to diseases and medium-sized bold seed. Seed multiplication was done on 10 ha during *rabi* (postrainy) season 2002/03 for popularization of this variety.

Punjab 2000: A New Large-seeded Desi Chickpea Variety for Punjab Province of Pakistan

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Chickpea *(Cicer arietinum)* is the major pulse crop in Pakistan, contributing 72.8% to the total area of pulses. It occupied an area of 961,400 ha during 2002-03 out of which 860,000 ha (89.5%) was in Punjab province (Anonymous 2003). Of this area in Punjab, 90.2% of the crop was planted as rainfed and of the rainfed area, 88.2% was concentrated in Thal. The Thal area comprises sand dunes and interdunal valleys having poor soil fertility (Anonymous 2002-03). In Thal, due to scarcity of soil moisture, desi chickpea varieties are grown and a large-seeded desi cultivar C 44 is predominant in the area. The produce of C 44 is locally known as *bittal* (large-seeded) quality. With the introduction of short or high input-responsive varieties of wheat *(Triticum aestivum),* the irrigated area of chickpea in Punjab declined from 184,000 ha (26% of the total area) in 1970-71 to 53,400 ha (6.8% of total area) in 2000-01. However, canal water shortage in recent years has favored cultivation of chickpea in irrigated area, as it requires less water as compared to wheat. Thus, the irrigated chickpea area has increased to 63,800 ha in 2001-02 and 84,000 ha in 2002-03 (Anonymous 2002-03). The farmers in irrigated areas use the type called *bittal* quality because of its attractive seed size. However, the crops planted on clay loam soils are affected by iron deficiency induced chlorosis in the early crop growth stage after the soil gets compact with the application of first irrigation/rainfall. But the same variety in sandy soils of Thal is not affected by iron-deficiency chlorosis (Ali et al. 1994). Sources of resistance to iron-deficiency chlorosis are available (Ali et al. 1988a) and the chlorosis is conditioned by a single recessive gene (Ali et al. 1988b). Recently, A 16, a near isogenic line of C 44 and having resistance to iron-deficiency chlorosis, was released as *Bittal* 98 to extend its cultivation in irrigated areas (Ali 1999). Further need was felt to develop a variety of chickpea, which can successfully be planted in rainfed as well as irrigated areas in the Punjab Province.

The chickpea variety development work was carried out at the Pulses Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan from 1988 to 1999. To develop a variety possessing resistance to iron-deficiency chlorosis for planting in irrigated areas and having adaptability to rainfed conditions, a cross was made during 1988/89 between the female parent C 87, a desi line possessing resistance to iron-deficiency chlorosis, and male parent C 44, the desi variety highly adapted to rainfed conditions of Thal. Pedigree method of breeding was adopted and line 93081 was selected in F_4 during 1992/93. It was tested for yield in yield nursery (non-replicated), yield trials (randomized complete block design) and sowing date yield trials (split plot design), during 1993/94 to 1998/99 and against ascochyta blight,

fusarium wilt and iron-deficiency chlorosis under artificially created disease conditions at Faisalabad during 1995/96 to 1998/99. The line was evaluated adopting the agronomic practices already established for desi varieties C 44 and Pb 91. The data were subjected to analysis of variance and LSD (0.05) was estimated for means separation adopting the procedures laid down by Little and Hills (1978).

On an average of 50 trials, including yield nursery, station yield trials, adaptation yield trials, sowing date yield trials and national uniform yield trials, conducted under both rainfed and irrigated conditions, the line 93081 produced an average yield of 1679 kg ha^{-1} as against 1314 kg ha^{-1} of control and showed 27.8% superiority over the check varieties Pb 91 or C 44 (Table 1). The line 93081 produced an average yield of 1653 kg ha^{-1} as against 1503 kg ha^{-1} of *Bittal* 98 in 27 national uniform yield trials conducted throughout the country during 1995/96 to 1998/99 (Table 2). It was rated as moderately resistant to ascochyta blight under artificially created blight epiphytotic conditions and also moderately resistant to fusarium wilt in simulated wilt conditions in a wilt sick plot during 1995/96 to 1998/99 (Table 3). It is also resistant to iron-deficiency chlorosis. It has 100-seed mass of 27.4 g as against 23.0 g of C 44 and 28.7 g of *Bittal* 98, the largest-seeded variety. The line 93081

Table 1. Yield performance of chickpea line 93081 in different yield trials during 1993/94 to 1998/99 in Pakistan.

Trials	Year	No. of trials	Yield (kg ha^{1})			Increase (%) in yield over check
			93081	Pb 91	LSD (0.05)	
Yield nursery (irrigated)	1993/94	1	3500	1979	Non-replicated	76.9
Station yield trials						
Irrigated	1994/95 to	6	1894	1445	324-574	31.1
Rainfed	1995/96	3	707	559	175-275	26.5
Adaptation yield trials (irrigated + rainfed)	1995/96 to 1997/98	11	1603	1387	178-561	15.6
National uniform yield trials (irrigated + rainfed)	1995/96 to 1998/99	27	1653	1270[1]		30.2
Sowing date yield trials						
17-10-1996 and 24-10-1998	1996/97 and	2	2519	1937	285-325	30.0
3-11-1996 and 6-11-1998	1998/99		2182	1892		15.3
Weighted average		50	1679	1314		27.8

1. Pb 91 or C 44 was used as control.

Table 2. Yield performance of line 93081 in national uniform yield trials during 1995/96 to 1998/99 in Pakistan.

Year	No. of locations	Yield (kg ha^{-1})		
		93081	*Bittal* 98	Check
1995/96	7	1773	1608	1026 (C 44)
1996/97	10	1246	1227	1171 (C 44)
1998/99	10	1977	1706	1541 (Pb 91)
Weighted average	27	1653	1503	1270

Table 3. The average reaction of line 93081 against blight, wilt and iron-deficiency chlorosis under artificial disease conditions at Faisalabad, Pakistan during 1995/96 to 1998/99.

Variety	Fusarium wilt (%)	Ascochyta blight score (1-9 scale)	Iron-deficiency chlorosis
93081	21-30	3	Resistant
C 87	21-30	3	Resistant
C 44	31-40	5	Susceptible
Pb 91	31-40	5	Resistant
Bittal 98	21-30	3	Resistant

has been released as Punjab 2000 by the Punjab Seed Council for cultivation in both rainfed and irrigated areas of Punjab in Pakistan.

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Agronomy/Physiology

Effect of Planting Methods and Irrigation on the Productivity of Chickpea Sown After Rice

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In the Punjab state of India, chickpea *(Cicer arietinum)* was sown on about 800,000 ha under rainfed conditions before the Green Revolution in 1965. By 2000, 95% area of the state became irrigated and due to the dominant rice (*Oryza sativa)*-wheat *(Triticum aestivum)* system only 8,000 ha area had remained under chickpea. Now again farmers have started to grow chickpea after the harvest of rice as high-yielding and disease resistant varieties such as PBG 1, GPF 2 and PBG 5 are available. Moreover, these varieties can be grown under irrigated conditions and show stable yield performance. In rice-chickpea system, the major problem farmers noticed is that the crop was damaged badly when irrigated due to failure of rains during the crop season. Soon after irrigation the crop turns pale yellow and plants start dying thereafter. Farmers' fields are quite large and when irrigation is given more water is absorbed by the soil and water remains stagnated due to poor percolation owing to hard pan formation because of puddling. This causes loss of oxygen in the root zone, possibly due to which plants do not respire well and plant nutrition uptake reduces thereby affecting the crop badly; consequently yields are very low. On heavy soils, excessive moisture under field conditions reduces the growth, nodulation, root growth and yield of chickpea drastically (Patel et al. 1987, Chandrakar et al. 1991). The number of nodules, leghemoglobin content and nitrogenase activity decreased when chickpea plants were flooded in polyethylene bags (Bishnoi and Krishnamoorthy 1991). However, in case chickpea is sown after crops other than rice [eg, maize *(Zea mays),* sorghum *(Sorghum bicolor),* pearl millet *(Pennisetum glaucum),* cotton *(Gossypium* sp), etc] where water stagnation is not a problem, no adverse effect of irrigation is observed. Therefore, field experiments on chickpea, sown after rice or maize, were undertaken at different locations with different planting methods and irrigation levels.

A field experiment comprising three planting methods (flat bed sowing at 30 cm row spacing; 2 rows of chickpea at 30 cm distance on 67.5 cm wide raised bed; and 3 rows of chickpea on 67.5 cm wide raised bed) and three irrigation levels (no irrigation; one irrigation at flower initiation; and two irrigations, first at vegetative stage 50 days after sowing and second at flower initiation) was conducted during 1998/99 at the Regional Research Station, Gurdaspur, Punjab, India where the preceding crop was maize. Rice was not sown on this land for the past 10 years. The experiment was laid out in the factorial randomized block design with three replications. In 1999/2000, it was conducted at the Bhupindra Rice Research Station, Punjab Agricultural University (PAU), Rauni, Punjab while in 2001/02 at the Krishi Vigyan Kendra, PAU, Langroya, Nawanshahar, Punjab after the preceding crop of rice. The soil of Langroya farm is heavy (sandy loam). During 2000/01 and 2001/02 non-replicated trials comprising four treatments [flat bed, no irrigation; flat bed, one irrigation; raised bed (2 rows), no irrigation; raised bed (2 rows), one irrigation] were undertaken as on-farm trials in farmers' fields. The plot size was 5.4 m x 40 m.

At Gurdaspur, effects due to planting methods and irrigation levels were not significant on the grain yield of chickpea sown after maize (Table 1). Yield of chickpea with one irrigation was higher by 8% than in treatment without irrigation whereas it was similar in treatment with

Table 1. Effect of planting methods and irrigation levels on the grain yield of chickpea sown after maize at Gurdaspur, Punjab, India, 1998/99.

	Grain yield (kg ha^{-1})			
Planting method	No irrigation	One irrigation[1]	Two irrigations[2]	Mean
Flat bed (30 cm row spacing)	1411	1348	1315	1358
Raised bed 67.5 cm wide (2 rows)	1200	1476	1359	1345
Raised bed 67.5 cm wide (3 rows)	1295	1397	1511	1401
Mean	1302	1407	1402	
CD at 5%				
Planting method = NS[3]				
Irrigation level = NS				
Interaction = NS				

1. At flower initiation.
2. At vegetative stage and flower initiation.
3. NS = Not significant.

Table 2. Effect of planting methods and irrigation levels on the grain yield of chickpea sown after rice at Rauni, Punjab, India, 1999/2000.

	Grain yield (kg ha^{-1})				
Planting method	No irrigation	One irrigation[1]	Two irrigations[2]	One irrigation[1] + 20 kg N ha^{-1} top dressing	Mean
Flat bed (30 cm row spacing)	1298	619	438	612	741
Raised bed 67.5 cm wide (2 rows)	1178	1411	1500	1502	1398
Raised bed 67.5 cm wide (3 rows)	1245	1464	1547	1576	1458
Mean	1240	1165	1162	1230	
CD at 5%					
Planting method = 82					
Irrigation level = NS[3]					
Interaction = 164					

1. At flower initiation.
2. At vegetative stage and flower initiation.
3. NS = Not significant.

two irrigations. The interaction effects were also not significant.

At Rauni, the effects due to planting methods were significant on the grain yield of chickpea sown after rice while irrigation levels did not influence the grain yield (Table 2). The flat bed treatment had almost half the yield levels as compared to raised bed treatments when one irrigation was given. The grain yield further reduced with two irrigations in flat bed. The low yields of chickpea in flat bed were due to the adverse effect of irrigation. The interaction effects between planting methods and irrigation levels were significant. The grain yields were reduced drastically in flat bed with one irrigation as well as with two irrigations. Treatment with no irrigation in raised bed with 2 or 3 rows yielded significantly less than the raised bed with one or two irrigations. The differences between one or two irrigations in raised bed were not significant.

At Langroya, crop sown on raised bed (both 2 and 3 rows) yielded significantly higher than that sown on flat bed (Table 3). No irrigation treatment was better than one irrigation. Although interaction effects were not significant, data indicate that irrigation application in the case of flat bed reduced the grain yield drastically. Interestingly, irrigation application in raised bed produced high yields.

In 2000/01, in on-farm trials with large-sized plots, one irrigation applied to the crop sown on flat bed reduced the grain yields drastically at both the test locations (Table 4). Raised bed (2 rows) plots without irrigation showed 12.5% decrease in yield than the flat bed plots without irrigation. However, crop sown on raised bed (2 rows) with one irrigation at pod initiation gave 7.9% higher yield over that sown on flat bed.

Results indicate that in rice-chickpea cropping system, application of irrigation to chickpea results in drastic reductions in the grain yield of crop sown on flat bed.

Table 3. Effect of planting methods and irrigation levels on the grain yield of chickpea sown after rice at Langroya, Punjab, India, 2001/02.

	Grain yield (kg ha^{-1})		
Planting method	No irrigation	One irrigation[1]	Mean
Flat bed (30 cm row spacing)	2259	1401	1830
Raised bed 67.5 cm wide (2 rows)	2124	2468	2291
Raised bed 67.5 cm wide (3 rows)	2322	2479	2399
Mean	2235	2116	
CD at 5%			
Planting method = 135			
Irrigation level = 110			
Interaction - NS[2]			

1. At flower initiation.
2. NS = Not significant.

Table 4. Effect of planting methods and irrigation levels on the grain yield of chickpea sown after rice in on-farm trials in Punjab, India during 2000-02.

	Grain yield (kg ha^{-1})			
Planting method	Kothe Rehlan (2000/01)	Sidhwanbet (2000/01)	Kothe Rehlan (2001/02)	Mean
Flat bed, no irrigation	1872	1500	2175	1849
Flat bed, one irrigation at pod initiation	365	640	488	497
Raised bed (2 rows), no irrigation	1695	1268	1890	1618
Raised bed (2 rows), one irrigation at pod initiation	2022	1674	2292	1996

However, application of irrigation to crop sown on raised bed proves beneficial.

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Response of Chickpea Seed Germination to Spermidine Treatment to Overcome Cold Injury

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Seed germination in chickpea *(Cicer arietinum)* is one of the sensitive phases to chilling. Soil temperatures <10°C may substantially reduce seed germination and seedling establishment especially in kabuli genotypes due to large seed size and thin seed coat (Chen et al. 1983). Germination as well as emergence can be drastically reduced due to imbibitional chilling injury and consequent infection by soilborne pathogens (Chen et al. 1983, Balasubramanian et al. 1998). The relative sensitivity of germination and subsequent seedling growth to chilling is not investigated in chickpea. Cold tolerance has been found to be associated with elevation of polyamines (Kim et al. 2002), which are low in molecular weight, non-protein, straight-chain, aliphatic hydrocarbon compounds with amino and imino groups that include putrescine (diamine), spermidine (triamine) and spermine (tetramine). They are implicated in stress protection and are involved in a wide range of biological processes due to their cationic nature that assist in their interaction with DNA, proteins, membrane phospholipids and cell wall polysaccharides (Kakkar and Sawhney 2002). No information exists on their involvement in response of chickpea to chilling stress. Hence, this study was conducted to: (1) investigate the relative sensitivity of different phases (commencing from seed germination till early seedling growth) to chilling stress; and (2) evaluate the protective effects of spermidine.

Seeds of kabuli chickpea genotype L 550 were surface sterilized with 0.1% mercuric chloride for 2 min and subsequently washed with distilled water twice. These seeds were subsequently subjected to the following treatments:

1. Stress at imbibition stage: Previous seed germination studies under 5, 8, 10, 15, 20 and 25°C (11 h light/13 h dark) for 10 days had shown no germination at 5°C, 22 ± 2.1% at 8°C and 33 ± 2.3% germination at 10°C. Soil temperatures <10°C are reported to be inhibitory for kabuli genotypes (Chen et al. 1983). Hence, 8°C was opted in this study to test the efficacy of spermidine. Seeds were grown in large petri dishes at 8°C (11 h light/13 h dark) containing 0.1, 0.5 and 1.0 mM spermidine for 15 days; distilled water was used as control.

2. Stress at germination (radicle emergence): Seeds were initially allowed to reach radicle emergence (5 mm length) stage by growing them in distilled water at 25°C for 48 h and then subjected to chilling stress (8°C) in spermidine (0.1, 0.5 and 1.0 mM) for 13 days; distilled water was used as control.

3. Stress at seedling stage: Seeds were germinated at 25°C in water and allowed to grow at the same temperature for 7 days (11 h light/13 h dark; irradiance 250 μmol m^{-2} s^{-1} at the surface of plants). These 7-day-old seedlings were subjected to 8°C (growth conditions as above) in spermidine (0.1, 0.5 and 1.0 mM) for 8 days; distilled water was used as control.

4. Seed soaking in spermidine: Seeds were soaked in 0.1, 0.5 and 1.0 mM of spermidine for 3, 6, 12 and 24 h at 20°C (11 h light/13 h dark); distilled water was used as control. These seeds were grown in pots (10 cm diameter and 10 cm height) filled with soil and kept at 8°C (11 h light/13 h dark; irradiance 250 μmol m^{-2} s^{-1} at the surface of plants) for germination and subsequent seedling growth for 20 days.

Observations were taken on electrolyte leakage (EL) (indicator of membrane damage) and 2,3,5-triphenyl tetrazolium chloride (TTC) reduction ability (indicator of mitochondrial stability) using methods of Lutts et al. (19%) and Steponkus and Lanphear (1967), respectively. Growth rate of seedlings was determined by measuring initial and final length of roots and shoots with respect to time.

Experiments were conducted in three replications and repeated four times. Almost similar trend was observed each time. Data was anaylzed for standard error and ANOVA using microstat software. Mean values are presented along with CD ($P<0.05$).

Chilling stress (8°C) at imbibition stage caused a marked increase in EL and decrease in TTC reduction ability in control indicating a severe damage to membranes and mitochondrial stability, respectively. In general, germination and root and shoot growth rates were relatively lower in control. Spermidine at 1 mM concentration reduced the EL and increased the TTC activity (Table 1). Germination increased by 3-fold and the time to emergence of radicle and plumule decreased significantly with 1 mM spermidine while growth rate of roots and shoots enhanced by 50 and 37%, respectively over control.

During stress at germination (radicle emergence), 0.5 mM spermidine was found to be comparatively more effective in reducing the chilling injury with less EL and increased TTC reduction ability (Table 2). The growth of roots and shoots increased by 66 and 42%, respectively with 0.5 mM spermidine.

Stress at seedling stage caused relatively less injury to membranes than the previous two stages as indicated by EL (Table 3). Spermidine at 0.1 mM was the most effective in mitigation of chilling injury at this stage while higher concentrations were relatively less effective. There was an increase of 47% in root and 81% in shoot growth rates.

These observations indicated that chilling injury during germination and early seedling growth could be prevented substantially with the use of spermidine in the growth medium. It was also apparent that imbibition phase was relatively more sensitive to chilling as indicated by the relatively higher damage to membranes (as EL), TTC reduction ability, germination and growth of roots and shoots. It has been reported earlier that chickpea, along with many other chilling-sensitive species, is very sensitive to imbibitional chilling injury (Tully et al. 1981). Chen et al. (1983) observed that the period of greatest sensitivity to cold corresponds to the first 30 min of imbibition. With decrease in temperature, leaching of several important cellular contents increases due to membrane injury that intensifies the damage to germinating seed (Chen et al. 1983). These authors also demonstrated the pre-sowing hydration of the seed at 20°C to reduce the effect of rapid imbibition and to protect the seed from chilling injury. In our subsequent experiment (Table 4), seeds pre-hydrated with various spermidine concentrations (0.1, 0.5 and 1.0 mM) for different duration (3-24 h) were raised under chilling temperature (8°C). In general, spermidine treatments mitigated the chilling effects on emergence, days to emergence and growth of the seedlings. Among these treatments, 12 h hydration with 0.5 mM spermidine proved to be most beneficial for these traits.

This investigation suggests that cold tolerance can be induced by exogenous application of spermidine, which possibly elevates the endogenous concentration. It has

Table 1. Effect of different concentrations of spermidine on various parameters during chilling stress at imbibitional stage of chickpea.

Spermidine concentration (mM)	Electrolyte leakage[1] (%)	TTC reduction ability[2] (%)	Germination after 7 days (%)	Radicle emergence (days)	Plumule emergence (days)	Root growth rate[3] (mm day^{-1})	Shoot growth rate[3] (mm day^{-1})
Control	85.2	24.1	23.4	3.0	7.2	1.2	0.8
0.1	84.8	31.2	28.4	2.8	6.8	1.6	0.9
0.5	60.1	41.4	48.6	2.4	5.8	1.8	1.1
1.0	32.5	78.2	70.2	2.0	5.1	2.3	1.8
CD at 5%	2.3	2.8	3.4	0.11	0.72	0.18	0.17
Mean	65.65	43.70	42.65	2.55	6.22	1.72	1.15
SEm	0.47	0.33	0.28	0.041	0.17	0.039	0.052
CV (%)	1.24	1.32	1.71	2.81	4.8	3.98	8.05

1. Whole seeds after 96 h of imbibition.
2. TTC = 2,3,5-triphenyl tetrazolium chloride. Whole seeds after 96 h of imbibition.
3. In 15-day-old seedlings.

been reported earlier that chilling-tolerant plants increase their polyamine levels to a greater extent than chilling-sensitive ones (Bouchereau et al. 1999) and exogenously supplemented polyamines may impart tolerance against chilling stress (Shen et al. 2000). Previous studies have also indicated that priming the chickpea seeds with growth regulators can enhance their performance under stress (Kaur et al. 2003). The mode of protection by spermidine is not well understood but appear to involve in stabilization of membranes and proteins as well as detoxification of oxidative molecules in stressed cells (Bouchereau et al. 1999).

Thus germination and seedling growth in kabuli chickpea genotypes under chilling conditions could be improved by seed treatment for 12 h with 0.5 mM spermidine. Also, genetic manipulation of polyamines for their enhanced activity might contribute to induction of cold tolerance in chickpea.

Table 2. Effect of different concentrations of spermidine on various parameters during chilling stress at germination of chickpea.

Spermidine concentration (mM)	Electrolyte leakage[1] (%)	TTC reduction ability[2] (%)	Plumule emergence (days)	Root growth rate[3] (mm day^{-1})	Shoot growth rate[3] (mm day^{-1})
Control	68.1	40.1	4.1	1.5	0.9
0.1	64.2	48.2	3.8	1.9	1.0
0.5	38.1	72.1	2.8	2.5	2.2
1.0	51.2	58.2	3.1	2.2	1.8
CD at 5%	3.1	2.8	0.52	0.12	0.13
Mean	55.4	54.6	3.45	2.02	1.47
SEm	0.61	0.64	0.13	0.035	0.05
CV (%)	1.92	2.05	6.89	2.96	6.0

1. Roots of 7-day-old seedlings.
2. TTC - 2, 3, 5 - triphenyl tetrazolium chloride. Roots of 7-day-old seedlings.
3. In 15-day-oId seedlings.

Table 3. Effect of different concentrations of spermidine on various parameters during chilling stress at seedling stage of chickpea between 7 and 15 days after sowing.

Spermidine concentration (mM)	Electrolyte leakage[1] (%)	TTC reduction ability[2] (%)	Root growth rate[3] (mm day^{-1})	Shoot growth rate[3] (mm day^{-1})
Control	60.1	49.1	1.9	1.1
0.1	35.1	75.1	2.8	2.0
0.5	41.1	68.2	2.4	1.9
1.0	48.2	52.2	2.1	1.6
CD at 5%	3.4	2.8	0.14	0.16
Mean	46.1	61.1	2.3	1.65
SEm	0.60	0.64	0.028	0.030
CV (%)	2.26	1.83	2.17	3.03

1. Roots of 7-day-old seedlings.
2. TTC = 2, 3, 5 - triphenyl tetrazolium chloride. Roots of 7-day-old seedlings.
3. In 15-day old seedlings.

Table 4. Effect of seed soaking for various periods and in different concentrations of spermidine on growth parameters of chilling-stressed chickpea plants[1].

	Control				0.1 mM spermidine				0.5 mM spermidine				1.0 mM spermidine			
Time (h)	Em (%)	Em (days)	RGR	SGR	Em (%)	Em (days)	RGR	SGR	Em (%)	Em (days)	RGR	SGR	Em (%)	Em (days)	RGR	SGR
3	28	11	1.60	1.12	31	10	1.58	1.20	48	11.0	1.62	1.20	50	11.0	1.64	1.34
6	36	11	1.62	1.22	40	10	1.63	1.20	62	9.5	1.79	1.90	64	9.5	1.74	1.80
12	42	9	1.74	1.64	59	9	1.79	1.80	82	7.0	2.80	2.20	71	8.0	2.20	1.94
24	40	10	1.68	1.31	41	10	1.71	1.60	78	8.0	2.10	1.92	62	9.0	1.80	1.80
CD at 5%	3.1	1.2	0.12	0.15	3.4	1.2	0.11	0.13	3.2	1.3	0.14	0.17	3.4	1.2	0.11	0.18
Mean	36.5	10.25	1.66	1.32	42.75	9.75	1.67	1.45	67.5	8.87	2.07	1.80	61.75	9.37	1.84	1.72
SEm	0.44	0.33	0.026	0.05	1.02	0.43	0.028	0.043	0.60	0.28	0.048	0.036	1.30	0.40	0.04	0.035
CV (%)	2.09	5.60	2.78	6.54	4.15	8.10	2.89	5.23	1.54	5.79	4.0	3.53	3.70	8.54	3.83	3.53

1. Em = Emergence; RGR = Root growth rate (mm day^{-1}); SGR = Shoot growth rate (mm day^{-1}).

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Screening Chickpea Mini-core Germplasm for Tolerance to Soil Salinity

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Chickpea (*Cicer arietinum*) is generally grown in the semi-arid regions where soil salinity is one of the major constraints for yield production (Rengasamy 2002). Extensive screening for salinity tolerance has been carried out under field conditions (Dua 1992) and subsequent recommendations of chickpea varieties suitable for cultivation in saline soils were made (Dua and Sharma 1995). However, most of these studies involved limited genetic base catering for narrow geographical region. To know the complete range of tolerance levels available in cultivated chickpea, it becomes necessary to evaluate the whole range of germplasm collection. The availability of a subset of the entire chickpea germplasm collection as mini-core collection (Upadhyaya and Ortiz 2001) provides access to evaluate a manageable number of accessions while capturing nearly the whole range of variation for responses to abiotic or biotic constraints limiting yield. Identification of larger number of salinity tolerant sources would also permit use of diverse sources for future breeding efforts and to ensure a better chance of success in improving the salinity adaptation of chickpea.

Evaluation of large number of accessions for yield responses to salinity under field conditions can be difficult due to the spatial and temporal variability. However, their pre-flowering stage response can be adequate for initial screening. Therefore, the main objectives of this study are to: (1) assess the extent of genetic variation available for salinity tolerance in the mini-core germplasm collection of chickpea at the vegetative stage of development; (2) identify accessions with contrasting salinity responses; and (3) assess the comparative level of tolerance available in chickpea breeding lines and popular varieties.

This screening was conducted in pots (24 cm diameter and 22 cm height, with 7 kg Vertisol) under open field conditions in an alpha lattice design (14 x 18) with three replications at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. The experiment was conducted between 19 December 2003 and 28 January 2004, with no rainfall events, at a minimum temperature of 8 to 19°C and maximum of 23 to 31°C. Chickpea mini-core germplasm accessions (211) and 41 popular varieties and breeding lines were grown in two salinity treatments: (1) Control: irrigated with tap water; and (2) Saline: irrigated with 100 mM NaCl solution to field capacity of the soil once at the time of sowing (resulting in EC of 1.7 dS m^{-1} of 1:2 soil : distilled water extract), and subsequently irrigated with tap water. Twelve seeds for each entry were sown on 19 December 2003 in four equally spaced hills in each pot and irrigated with tap water or saline solution to field

Table 1. Trial means, range of best linear unbiased predicted means and analysis of variance of shoot biomass under salinity and their ratio as that of control of 252 chickpea entries sampled at 15, 21, 28 and 40 days after sowing (DAS) at ICRISAT, Patancheru, India during 2003/04.

Trait	Trial mean	Range of predicted means	SEd	σ^2 ±SE	CV (%)	Heritability in broad sense (h^2)
Shoot dry matter (g plant') under 100 mM salinity						
15 DAS	0.061	0.029-0.133	0.0120	0.00053 ± 0.00005	24.8	0.698
21 DAS	0.111	0.073-0.268	0.0224	0.00153 ± 0.00016	25.8	0.652
28 DAS	0.173	0.082-0.371	0.0290	0.00476 ± 0.00047	20.5	0.792
40 DAS	0.309	0.117-0.935	0.0828	0.03158 ±0.00317	33.0	0.752
Ratio of shoot dry matter under 100 mM salinity as that of control						
15 DAS	0.621	0.524-0.883	0.1209	0.01234 ±0.00256	32.0	0.234
21 DAS	0.657	0.606-0.795	0.0893	0.00500 ± 0.00248	35.3	0.085
28 DAS	0.606	0.426-0.974	0.1117	0.01471 ± 0.00236	28.4	0.331
40 DAS	0.420	0.204-0.842	0.1312	0.02724 ± 0.00363	44.1	0.442

capacity. Six plants pot^{-1} were retained after thinning at 15 days after sowing (DAS). The plants removed while thinning formed the first sample. Subsequently, two plants per pot were sampled at 21, 28 and 40 DAS. Plants in each sample were separated into root (extractable) and shoot, oven dried at 60°C for 3 days and the dry mass then recorded. The roots were fully extracted from the soil at 40 DAS, by washing the soil from the roots. The shoot biomass for each sample was analyzed using the statistical procedure of residual maximum likelihood (ReML) by treating the replications and replications x block effects as fixed and the accessions as random effects to obtain the unbiased estimates of the variance components and the best linear predictions (BLUPs) of the performance of the 252 germplasm accessions and varieties. Heritability in broad sense was estimated as $h^2 = \sigma^2_g/(\sigma^2_g + \sigma^2_e)$. The significance of genetic variability among the accessions was assessed from the standard error of the estimate of genetic variance σ^2_g, assuming the ratio $\sigma^2_g/SE\ (\sigma^2_g)$ to follow normal distribution asymptotically. The salinity susceptibility index (SSI) was calculated following Fisher and Maurer (1978) based on the shoot biomass of each accession.

The SSI and the individual accession means of shoot biomass under salinity stress at 40 DAS were used for clustering the accessions into different classes using Numerical Taxonomy and Multivariate Analysis System (NTSYSPC), version 2.1 (Exeter Software, New York, USA). Similarity/dissimilarity matrix was obtained based on Euclidean distances and thus the accessions were grouped on the basis of UPGMA (unweighted pair-group method of arithmetic average).

Under salinity stress, there was a delay in seedling emergence by 1 or 2 days in all accessions. The reduction in number of seedlings emerged due to salinity stress was marginal with no accession x salinity interaction. The shoot biomass under salinity and the ratio of shoot biomass production under salinity to that of the control showed significant variation at all stages of sampling (Table 1). There was a considerable accession xsalinity interaction (P = 0.001 for samples at 15, 28 and 40 DAS and P = 0.05 for 21 DAS) at all the sampling periods. As wider range of genetic variability for salinity response occurred at 40 DAS, the chickpea accessions were clustered using both SSI and shoot biomass under salinity recorded at 40 DAS. Both the actual productivity under salinity and the SSI are considered equally important. SSI was used to account for the variation of the entries in early growth vigor. The cluster analysis showed four major groups at a similarity coefficient of 75%. The broad sense heritability of shoot biomass production under salinity was considerably high at all stages of sampling (0.65 to 0.79) whereas the ratio of shoot biomass produced under salinity to that of control was relatively low (0.09 to 0.44). The heritability of the latter trait reflects more of the salinity response potential because the growth rates of the accessions are expected to vary depending upon the intrinsic growth vigor and the timing of the exponential growth, and the productivity under salinity is expressed as a fraction of an accession's performance under non-saline conditions. Azhar and McNeilly (1988) reported that the narrow sense heritability value (0.51) estimated for relative root length in sorghum (*Sorghum bicolor*) at 100 mM concentration has been shown to reduce further at 150 mM concentration (0.19). In a relatively more salinity sensitive species such as rice (*Oryza sativa*), the narrow sense (0.198) and broad sense (0.367) heritability values for K/Na ratio, at 12 dS m^{-1} culture medium conditions, were shown to be very low (Gregorio and Senadhira 1993) and close to those measured in our study.

SSI of the accessions was more closely correlated with the shoot biomass under salinity (-0.941) than that of the control (-0.375). The accessions that possessed low SSI and high shoot biomass under salinity stress at 40 DAS were grouped into highly tolerant category and the ones with high SSI and low shoot biomass as highly sensitive (Table 2). The list of accessions under the 'highly tolerant',

Table 2. Cluster group means of salinity susceptibility index (SSI) and shoot biomass under saline condition (100 mM NaCl) at 40 days after sowing and the comparative reaction of 252 chickpea germplasm accessions at ICRISAT, Patancheru, India.

Chickpea accessions	Reaction	SSI	Shoot biomass in control (g plant^{-1})	Shoot biomass in saline treatment (g plant^{-1})
10	Highly tolerant	0.318	0.930	0.756
33	Tolerant	0.606	0.847	0.546
113	Sensitive	0.945	0.729	0.326
96	Highly sensitive	1.318	0.707	0.161

Table 3. Chickpea accessions/genotypes grouped on the basis of salinity susceptibility index (SSI) and shoot biomass production under 100 mM saline water applied condition at 40 days after sowing at ICRISAT, Patancheru, India.

Cluster group	Accession/genotype[1]
Highly tolerant	ICC 10755 (2), ICC 13124 (7), ICC 13357 (8), ICC 15406 (10), ICC 15697 (6), ICCV 92318 (9), ICCV 92337 (5), ICCV 95332 (4), ICCV 95334 (1) and *Jumbo* 2[2] (3)
Tolerant	ICC 1915 (38), ICC 2277 (24), ICC 2919 (29), ICC 4958 (35), ICC 7255 (30), ICC 7272 (12), ICC 7554 (37), ICC 7668 (21), ICC 8151 (47), ICC 8261 (13), ICC 8522 (36), ICC 8855 (23), ICC 9137 (16), ICC 9862 (15), ICCV 10341 (33), ICC 10885 (44), ICC 11879 (25), ICC 12328 (32), ICCV 13523 (27), ICC 13816 (28), ICC 14199 (39), ICC 14595 (17), ICCV 15333 (20), ICC 15510 (19), ICC 15518 (43), ICC 15802 (18), ICC 16796 (34), ICCV 2 (52), ICCV 88202 (26), ICCV 92504 (14), ICCV 95311 (31), ICCV 95333 (11) and ICCV 96329 (22)
Highly sensitive	ICC 283 (171), ICC 440 (153), ICC 637 (228), ICC 708 (203), ICC 762 (192), ICC 1052 (241), ICC 1098(201), ICC 1161 (194), ICC 1164 (176), ICC 1180 (174), ICC 1397(163), ICC 1510 (158), ICC 1710 (212), ICC 1715 (200), ICC 1923 (175), ICC 2065 (222), ICC 2072 (180), ICC 2507 (247), ICC 2720 (234), ICC 2884 (250), ICC 2969 (177), ICC 3218 (198), ICC 3230 (162), ICC 3362 (246), ICC 3512 (217), ICC 3631 (245), ICC 3761 (238), ICC 3776 (248), ICC 3946 (249), ICC 4182 (230), ICC 4418 (184), ICC 4463 (240), ICC 4593 (211), ICC 4639 (181), ICC 4657 (179), ICC 4814 (242), ICC 5383 (167), ICC 5434 (220), ICC 5845 (224), ICC 5878 (232), ICC 5879 (237), ICC 6279 (210), ICC 6293 (226), ICC 6537 (168), ICC 6571 (202), ICC 6802 (231), ICC 6816 (214), ICC 7184 (252), ICC 7323 (243), ICC 8058 (197), ICC 8195 (193), ICC 8607 (218), ICC 8621 (166), ICC 9643 (236), ICC 9755 (170), ICC 9848 (207), ICC 10945 (190), ICC 11198 (233), ICC 11584 (187), ICC 11627 (223), ICC 11664 (209), ICC 11944 (244), ICC 12299 (229), ICC 12307 (159), ICC 12537 (199), ICC 12654 (216), ICC 12726 (219), ICC 12824 (213), ICC 12851 (215), ICC 12866 (173), ICC 12916 (239), ICC 12928 (205), ICC 13187 (235), ICC 13283 (208), ICC 13441 (225), ICC 13524 (206), ICC 13628 (188), ICC 13764 (183). ICC 13892 (154), ICC 14077 (195), ICC 14778 (191), ICC 14815 (185), ICC 14831 (165), ICC 15567 (251), ICC 15612 (178), ICC 16269 (189), ICCC 37 (196), ICCL 87322 (204), ICCV 1 (160), ICCV 96752 (164), Chafa (227), E 100YM (221), *Gulabi*[2] (186), JG 62 (172), Myles (169) and Pant G1 14 (182)

1. Values in parentheses following each accession are the SSI rank out of 252. Accessions showing sensitive reaction are not listed.
2. These were collections from farmer's fields and names are popular among fanners. No accession numbers are available for these entries.

'tolerant' and 'highly sensitive' categories is presented in Table 3. The accessions that were grouped under the highly sensitive category were those that died or were close to mortality under salinity at 40 DAS. The highly tolerant accessions showed less symptoms of salinity effect such as yellowing of the basal leaves in kabuli types or the characteristic anthocyanin pigment appearance in desi types. Most of the highly salinity tolerant entries such as ICCVs 95334, 95332, 92337 and 92318 were kabuli types that were bred at ICRISAT, Patancheru. Majority of the highly sensitive accessions were of desi type. Such screenings were carried out and grouping on the basis of responses were made at the seedling stages in chickpea (Al-Muttawa 2003).

This screening is being planned for repetition during the postrainy season of 2004/05 to confirm the performance of the accessions. Also, determination of various ionic compositions of the plant tissues is being carried out to investigate mechanisms of salt tolerance.

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Chickpea Cultivation in Rice-growing Area of Punjab Province of Pakistan: Potential and Constraints

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Among various agricultural production systems adopted in Pakistan, rice (*Oryza sativa) - wheat (Triticum aestivum)* is extremely important. The total area under rice-wheat is about 1.6 million ha, mostly in the Punjab province. The sustainability of rice-wheat system is under threat in the country due to productivity stagnation, deteriorating soil fertility and increased risk of weeds, pests and diseases (Johansen et al. 2000). The system is inherently exhaustive and disturbs balance of mineral nutrients. Continuous practice of rice-wheat rotation has intensified deficiencies of mineral nutrients (Zia et al. 1992). Development of sustainable cropping systems needs reintroduction of legumes in cereal dominated cropping systems.

Chickpea (*Cicer arietinum)* is the most important food legume grown in Pakistan but its cultivation has traditionally been associated with marginal soils by subsistence farmers under rainfed conditions. The rice-growing belt in Punjab appears to have great potential for chickpea production and its area can be increased through its introduction in the districts Hafizabad, Sheikhupura, Gujranwala, Sialkot and Narowal. But to support chickpea in rice-based system, high-yielding, disease resistant varieties and better management practices for preparation of compacted rice soils are needed (Haqqani et al. 2000). In view of the beneficial role of legumes to enhance sustainability of rice-based system, an attempt was made to generate information on intervention of chickpea in rice-based system and to suggest future research and development needs.

A two-member team of pulses agronomists from the National Agricultural Research Centre (NARC), Islamabad, Pakistan with financial help of the rice-wheat project conducted an informal exploratory survey from 23 February to 1 March 2003 of five major rice-growing districts of Punjab. Overall about fifty experienced farmers and personnel of the Departments of Agriculture Extension and Adaptive Research in these districts were interviewed about the present situation and further prospects of chickpea crop in rice-wheat rotation. The main objectives were to:

- Determine present status of chickpea in rice-growing area and existing chickpea-based cropping systems; and
- Explore possibilities for the reintroduction of chickpea cultivation in rice-wheat cropping system.

Findings

According to the views of agriculture experts and farmers, there is very little scope of pulses in irrigated agriculture in general and that of chickpea in particular. Farmers grow chickpea on limited scale only in drought years as a temporary intervention (Tables 1 and 2). Few farmers grow chickpea and sell the green pods and earn a sizeable income. Farmers adopt rotations involving pea (*Pisum sativum),* potato (*Solarium tuberosum),* onion (*Allium cepa),* fodder and off-season cucumber (*Cucumis sativus).* Rice, wheat, sugarcane (*Saccharum officinarum)* and sunflower (*Helianthus annuus)* are the main mandate crops in the area and every training program of farmers at village level is designed according to the needs of these crops. Introduction of chickpea in the area requires a

strong policy by the provincial government highlighting its economics through training programs and publicity on television and radio. Some economically viable rotations being practiced by the rice growers are: (1) rice-wheat-rice; (2) rice-wheat-maize (*Zea mays*) fodder-potato; (3) rice-pea-wheat; (4) rice-potato-wheat; (5) rice-maize fodder-wheat; and (6) rice-potato muskmelon (*Cucumis melo*).

Farmers find it difficult to grow chickpea after rice because rice is harvested very late and seedbed preparation for chickpea takes much time due to high moisture content of the soil. Mostly the fine basmati rice is grown in this area; about 70% of rice area is covered by fine rice variety Super Basmati, which matures in late November when normal sowing time for chickpea ends. There is hardly any prospect of relay cropping chickpea in rice as hard paddy fields and dense crop stand hinder germination and emergence. Similarly if chickpea is sown in the rice-wheat rotation, the next rice crop cannot be planted due to late maturity of this crop. For successful cultivation of chickpea it has to be sown in October while Super Basmati is commonly harvested around 30 November. According to farmers, chickpea varieties which could be planted late, ie, in November, could prove successful. Major constraints of chickpea cultivation are: (1) high weed infestation; (2) high insect (pod borer) attack; (3) wet conditions and poor drainage of the soil due to clayey nature; (4) excessive vegetative growth followed by less pod bearing; and (5) more income from rice and wheat which are high-yielding and safer crops.

Table 1. Area ('000 ha) of rice, wheat and chickpea in rice-growing districts of Punjab, Pakistan during 2002-03.

District	Rice	Wheat	Chickpea
Gujranwala	224.5	214.2	0.71
Sheikhupura	283.4	230.8	0.41
Sialkot	144.0	183.0	0.22
Narowal	72.4	129.7	0.93
Hafizabad	108.3	130.6	0.73
Total	832.6	888.3	3.00

Source: Department of Agriculture Extension, Government of Punjab, Pakistan.

Conclusions and Recommendations

- Severe weed infestation in chickpea fields is a serious problem; hence, adequate experimentation is needed to find out suitable weedicides.
- Chickpea is highly prone to pod borer attack. Its introduction in rice-wheat sequence requires adequate measures to control the insect.
- Soils remain waterlogged due to subsequent winter rains. Chickpea does not withstand waterlogging although there is no problem of land preparation, sowing and adequate plant stand per se. Drainage of the area needs to be improved through open ditch drains.
- Improved production technology of chickpea should be verified at research farms as well as on farmers' fields before taking up large-scale cultivation.

Table 2. Area ('000 ha) of chickpea in rice-growing districts of Punjab, Pakistan during last sixteen years[1].

District	1986/87 to 1989/90	1990/91 to 1993/94	1994/95 to 1997/98	1998/99 to 2001/02
Gujranwala	3.63	2.30	0.80	0.63
Hafizabad	NA[2]	1.40[3]	1.58	0.88
Sheikhupura	2.00	1.35	1.45	0.68
Sialkot	2.47	0.57	0.25	0.15
Narowal	-	0.43[4]	0.67	0.53
Total	8.10	6.05	4.75	2.87

1. Data are means of four years.
2. NA = Data not available.
3. Data for 1 year (1993/94).
4. Mean of 3 years (1991/92, 1992/93. 1993/94).

Source: Economic Wing, Ministry of Food, Agriculture and Livestock, Government of Pakistan, Pakistan.

- Reintroduction of chickpea in irrigated ecology of rice-wheat would promise a good future for this important legume provided appropriate agronomic and plant protection management is ensured.

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Pathology

A Consensus Set of Differential Lines for Identifying Races of *Fusarium oxysporum* f sp *ciceris*

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Fusarium wilt caused by *Fusarium oxysporum* f sp *ciceris* is one of the most important diseases of chickpea *(Cicer arietinum)* and is reported to cause annual yield losses of 10-15% (Jalali and Chand 1992). Eight races of the pathogen have been reported (Haware and Nene 1982, Jimenez-Diaz et al. 1993), out of which four (1, 2, 3 and 4) have been reported from India and five (0, 1A, 1B/C, 5 and 6) from California and Spain. Several sets of differential lines have been used to identify races of *F. oxysporum* f sp *ciceris* since the first report of variability in the pathogen (Haware and Nene 1982). The disease scoring scale used to phenotype resistance and susceptibility in differential lines has varied considerably among different studies (Table 1). The lines scored as resistant in one study might have been categorized as medium/moderately susceptible/intermediate in other studies and vice-versa. The differential sets used to date also lack line(s) that can differentiate between races 2 and 3. Since resistance to wilt in chickpea has been shown to be race specific and governed by major resistance genes, the ideal differential set should be comprised of lines with either near 100% or 0% wilt incidence. In this study, we developed a set of differential lines to identify *F. oxysporum* f sp *ciceris* races after testing 31 chickpea lines and 100 F_7 recombinant inbred lines (RILs) derived from a cross of WR 315 with C 104 for reaction to five races of the pathogen.

Twenty-nine *C. arietinum* lines, two *C. reticulatum* lines and 100 F_7 RILs were evaluated for reaction to races 1, 2, 3, 4 and 5. WR 315, one of the parents of the RILs, is resistant to races 1, 2, 3, 4 and 5 whereas the other parent, C 104, is susceptible to these races. The experiment was conducted in a replicated trial with three replications per line and 10 plants per replication. The lines giving

differential reaction to the five races were re-evaluated in another experiment using the same procedure with three replications. The chickpea plants were grown for two to three weeks in trays (50 cm length x 25 cm width x 5.6 cm depth) filled with perlite. For inoculum preparation, cultures of the different races were grown in V8 medium at 25°C at 100 rpm under continuous fluorescent light for 21 days. At the 3-4 leaf stage, one fifth of the lowermost portion of the roots was cut and the roots were dipped for five minutes in inoculum ($1x\ 10^6$ spores ml^{-1}) of either one of the races 1, 2, 3, 4 or 5 depending upon the treatment. The inoculated plants were transferred to larger trays (50 cm length x 35 cm width x 10.6 cm depth) filled with 1:1 mixture of potting soil and perlite and were grown to the termination of the experiment. The trays were supplied with nutrient solution [10% N, 10% P_2O_5, 10% K_2O, 0.025% Mg, 0.0034% B, 0.0018% Cu (chelated), 0.025% Fe (chelated), 0.0125% Mn (chelated), 0.00045% Mo and 0.00125% Zn] once a week for first two weeks after transfer and twice a week thereafter. The inoculated plants were grown under greenhouse conditions with a temperature regime of 26/22°C for 12/12 h under 16/8 h fluorescent light. The wilt score based on disease incidence (0-10% = resistant, 11-89% = intermediate, 90-100% = susceptible) for each line was recorded 8 weeks after inoculation.

The wilt incidence for each line was recorded and the data used to select ten lines as a differential set based on their ability to differentiate five races of the pathogen (Table 2). JG 62 and P 2245 were susceptible whereas BG 212 and WR 315 were resistant to all the races we used. Sanford was resistant to race 1 and susceptible to four other races. Another differential line, CRIL-1-53 was susceptible to race 1 but resistant to other four races. CRIL-1-94 differentiated between race 2 and race 3, and was susceptible to race 2 (100% wilt) and resistant to race 3 (0% wilt). Reaction of CRIL-1-94 to races 3 and 2 is shown in Figure 1. CRIL-1-94 was resistant to race 1 and intermediate to races 4 and 5. ICC 7537 and CRIL-1-17 were susceptible to race 4 and resistant to other races whereas CRIL-1-36 was resistant to race 5, susceptible to races 2, 3 and 4 and intermediate in reaction to race 1. In addition to differentiating these races, this set is expected to differentiate between race 0 and other races as JG 62 has been reported to be resistant to race 0 and susceptible to all other races (Jimenez-Diaz et al. 1989, Tullu 1996).

The proposed differential set comprised of 10 lines and is smaller in size compared to the set of 22 lines used by Tullu (1996). We observed consistency between replications in our results that might be primarily because of the controlled pathogen and environmental conditions used for disease evaluation. We also speculate that differences in disease phenotype of these lines, especially the RILs, after inoculation with different races might be due to one or a few major resistance genes as single genes in WR 315 (resistant) have been found to confer resistance to races 1, 2, 3, 4 and 5 compared to C 104 (susceptible). This is further supported by the fact that

Figure 1. Reaction of CRIL-1-94 to race 3 (left) and race 2 (right) of *Fusarium oxysporum* f sp *ciceris* at seven weeks after inoculation. (Note: The plants were grown under similar conditions in a single tray and inoculated at the same time.)

Table 1. Disease scoring scales used by various research workers to phenotype chickpea differential lines for resistance/ susceptibility to races of *Fusarium oxysporum* f sp *ciceris.*

	Disease scoring scale (% wilt incidence)		
Reference	Resistant	Moderately susceptible	Susceptible
Haware and Nene (1982)	0-20	21-50	>50
Phillips (1988)	0-20	21-50[1]	>50
Jimenez-Diaz et al. (1989)	0-33	34-66	67-100
El-Hadi(1993)	1-10	11-50	51-100
Tullu(1996)	1-10	11-90[2]	91-100

1. Disease reaction: Medium.
2. Disease reaction: Intermediate.

Table 2. Reaction of chickpea wilt differential lines to five races of *Fusarium oxysporum* f sp *ciceris*[1].

Differential line[2]	Alternative identifier[3]	Race 1	Race 2	Race 3	Race 4	Race 5
JG 62	W6-24867	S (100)	S (94.3)	S (100)	S(100)	S (100)
P 2245	W6-24868	S (100)	S (100)	S (100)	S (100)	S (100)
Sanford	W6-24869	R (0)	S (100)	S (100)	S (100)	S (95)
CRIL-1-53	W6-24870	S (100)	R (0)	R (0)	R (0)	R (0)
CRIL-1-94	W6-24871	R (0)	S (100)	R (0)	1 (36.4)	1 (30)
CRIL-1-17	W6-24872	R (0)	R (0)	R (0)	S (100)	R (0)
ICC 7537	W6-24873	R (0)	R (3.3)	R (0)	S (100)	R (0)
CRIL-1-36	W6-24874	1 (33.3)	S (100)	S (100)	S (100)	R (0)
BG 212	W6-24875	R (0)	R (0)	R (0)	R (0)	R (0)
WR 315	W6-24876	R (0)	R (0)	R (0)	R (0)	R (0)

1. S = susceptible; R = resistant; I = intermediate. Disease incidence (%) is given in parentheses.
2. Either of the differential lines can be used: JG 62 or P 2245; CRIL-1-17 or ICC 7537; BG 212 or WR 315.
3. Accessions available from the USDA Western Regional Plant Introduction Station, Pullman, Washington, USA.

almost all plants of the susceptible lines wilted whereas those of resistant lines remained healthy after inoculation with pathogen races. Line C 104 is known to wilt late after inoculation with race 1 (Upadhyaya et al. 1983) and was not included in the differential set. To facilitate precise race identification, we tried to select lines with 0 or 100% wilt and avoided the inclusion of lines with intermediate reaction except CRIL-1-94 which is intermediate in reaction to races 4 and 5 and CRIL-1-36 which is intermediate in reaction to race 1. CRIL-1-94 was one of the best lines for differentiating between race 2 (100% wilted) and race 3 (0% wilted). CRIL-1-36 differentiated between race 4 (100% wilted) and race 5 (0% wilted). The new set is expected to be more cost effective because of its smaller size, and greater in precision in identifying races of *F. oxysporum* f sp *ciceris* when compared to earlier differential sets. The set of differential lines will be maintained as a special collection and may be obtained on request to the US National Plant Germplasm System (http://www.ars-grin.gov/npgs/).

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Evaluation of Chickpea Lines for Resistance to Dry Root Rot Caused by *Rhizoctonia bataticola*

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Dry root rot, caused by *Rhizoctonia bataticola,* is one of the most important and widespread soilborne diseases of chickpea *(Cicer arietinum)* grown between latitudes 20° N and 20° S, where the climate is relatively dry and warm. Dry root rot generally appears during late flowering and podding stages and the infected plants appear completely dried. The root system of diseased plant shows extensive rotting with most of the lateral roots destroyed. The rotten roots are brittle and minute sclerotial bodies appear in the pith cavity and on the outer surface of the tap root.

Chemical control of dry root rot is not effective as *R. bataticola* has a broad host range and survives in soil for longer periods in the form of sclerotia. The sclerotia can survive up to 10 months even in the absence of host plants and under prevailing dry soil conditions. Use of host plant resistance is the most economical approach for management of dry root rot in chickpea. A few chickpea lines with field tolerance to dry root rot have been identified, but high levels of resistance are scarce in cultivated genotypes. Wilt caused by *Fusarium oxysporum* f sp *ciceris* is another important soilborne disease of chickpea, and combined resistance to dry root rot and wilt is desirable. Combined resistance to fusarium wilt and dry root rot has been identified in wild *Cicer* spp (Reddy et al. 1991).

In this study, 29 chickpea germplasm accessions and 10 cultivars received from the Genetic Resources Unit of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India were screened

Table 1. Reaction of chickpea accessions to dry root rot infection in screening by paper towel technique at ICRISAT, Patancheru, India, 2003.

Accession	Origin	Disease score			Disease reaction[1]
		Experiment 1	Experiment 2	Mean	
ICC 1376	India	4.3	5.0	4.7	M
ICC 3782	India	7.0	6.3	6.7	S
ICC 4963	India	7.0	7.0	7.0	S
ICC 5003	India	5.0	5.0	5.0	M
ICC 6679	Iran	7.0	7.0	7.0	S
ICC 6743	Iran	7.0	7.0	7.0	**s**
ICC 10803	India	8.3	9.0	8.7	HS
ICC 10894	India	5.0	4.3	4.7	M
ICC 11323	ICRISAT, India	7.0	7.0	7.0	S
ICC 12247	ICRISAT, India	6.3	7.0	6.7	S
ICC 12249	ICRISAT, India	5.0	5.0	5.0	M
ICC 12263	India	5.0	5.0	5.0	M
ICC 12428	ICRISAT, India	9.0	9.0	9.0	HS
ICC 12451	ICRISAT, India	5.0	5.0	5.0	M
ICC 14375	ICRISAT, India	7.0	6.3	6.7	S
ICC 14380	ICRISAT, India	5.0	4.3	4.7	M
ICC 14390	ICRISAT, India	9.0	9.0	9.0	HS
ICC 14393	ICRISAT, India	7.0	7.0	7.0	S
ICC 14395	ICRISAT, India	3.0	3.0	3.0	R
ICC 14396	ICRISAT, India	7.0	6.3	6.7	S
ICC 14397	ICRISAT, India	5.0	4.3	4.7	M
ICC 14401	ICRISAT, India	6.3	7.0	6.7	S
ICC 14431	ICRISAT, India	5.0	5.0	5.0	M
ICC 14432	ICRISAT, India	5.0	5.0	5.0	M

continued

Table 1. ***continued***

Accession	Origin	Disease score			Disease reaction[1]
		Experiment 1	Experiment 2	Mean	
ICC 14441	Italy	5.0	5.0	5.0	M
ICC 14443	Italy	4.3	5.7	5.0	M
ICC 14447	Italy	5.0	4.3	4.7	M
ICC 14449	USA	7.0	7.0	7.0	S
ICC 15167	India	5.0	5.0	5.0	M
ICCC 42	ICRISAT, India	5.0	5.0	5.0	M
ICCL 80001	ICRISAT, India	5.0	5.0	5.0	M
ICCL 80003	ICRISAT, India	5.0	7.0	6.0	S
ICCL 81015	ICRISAT, India	5.0	5.0	5.0	M
ICCL 83003	ICRISAT, India	7.0	7.0	7.0	S
ICCL 83110	ICRISAT, India	7.0	7.0	7.0	S
ICCL 85105	ICRISAT, India	7.0	6.3	6.7	S
ICCL 89220	ICRISAT, India	6.3	7.0	6.7	S
ICCV 2	ICRISAT, India	3.0	3.0	3.0	R
ICCV 5	ICRISAT. India	5.7	4.3	5.0	M
ICCX830203-BH-BH-10H	ICRISAT, India	7.0	7.0	7.0	S
ICCX830203-BH-BH-11H	ICRISAT, India	3.0	3.0	3.0	R
ICCX830203-BH-BH-13H-BH	ICRISAT, India	7.0	6.3	6.7	S
ICCX830235-BH-BH-5H	ICRISAT, India	5.0	5.0	5.0	M
ICCX830263-BH-BH-13H-BH	ICRISAT, India	5.0	5.0	5.0	M
ICCX840496-BP-19H-BH	ICRISAT, India	5.0	3.7	4.4	M
ICCX850496-BP-7H-BH	ICRISAT, India	5.0	5.0	5.0	M
ICCX850636-BH-26H-BH	ICRISAT, India	5.7	6.3	6.0	S
ICC 11088 (control)	India	9.0	9.0	9.0	HS
ICC 12267 (control)	ICRISAT, India	9.0	9.0	9.0	HS

1. R = resistant; M = moderately resistant; S = susceptible; HS = highly susceptible.

for their resistance to dry root rot using paper towel technique (Nene et al. 1981). In addition, 8 advanced breeding lines that were identified to have field resistance (<20% plants infected) either to wilt, dry root rot or collar rot *(Sclerotium rolfsii)* in multiple disease sick plot at ICRISAT were also evaluated to confirm their resistance to dry root rot. Eight-day-old seedlings were used for artificial inoculation and the inoculated seedlings were incubated at 35°C with 12 h photoperiod. The dry root rot severity was scored on a 1-9 rating scale on the 8th day after inoculation. Fifteen seedlings of each accession were considered as one replication, and the experiment consisted of three replications and was repeated once.

Based on the disease score the accessions were grouped as immune (disease score = 1), resistant (disease score >1 and <3), moderately resistant (disease score >3 and <5), susceptible (disease score>5 and <7*)* and highly susceptible (disease score >7). Of the 47 lines tested, none were immune to dry root rot. One germplasm accession (ICC 14395), a cultivar (ICCV 2) and an advanced breeding line (ICC X 830203-BH-BH-11H) were resistant to dry root rot. Of the remaining lines, 22 were moderately resistant, 19 susceptible and 3 highly susceptible (Table 1). The disease severity in the two susceptible lines BG 212 and ICC 12267 used as control was rated 9. The identified genotypes can be used as additional sources of resistance to dry root rot.

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Use of Grafting to Study Chickpea Resistance to Ascochyta Blight

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Resistance to ascochyta blight in chickpea (*Cicer arietinum*) has been extensively used in managing the disease. Many chickpea accessions resistant to ascochyta blight have been identified (Singh et al. 1997). However, the resistance mechanisms of chickpea to ascochyta blight are still not well understood at the biochemical and physiological levels, despite several genetic mechanisms proposed (Udupa and Baum 2003). *Ascochyta rabiei,* the causal agent of ascochyta blight of chickpea, is known to produce several phytotoxins that have been shown to be associated with virulence factors in the pathogen (Hamid and Strange 2000). Interactions of plants with phytotoxins can be either through receptors resulting in a susceptible reaction or through detoxifying enzymes resulting in a resistant reaction. Hamid and Strange (2000) identified a detoxifying mechanism in chickpea for resistance to ascochyta blight. Our objective was to study whether such disease-mediating molecules (either toxin receptors, detoxifying enzymes or other disease-mediating agents) were translocated through different parts of the plant by using reciprocal grafting between resistant and susceptible chickpea genotypes. Revealing translocation of such disease-mediating molecules will allow us to design experiments to further study the resistance mechanisms of chickpea to *A. rabiei.*

The grafting procedure was carried out on two-week-old plants. The scions (shoots) were cut at 10 cm from the tip with 2 to 3 open leaves. Approximately 2 cm at the base, the scions were cut into a V shape. The rootstock plants were decapitated about 3 cm from soil line, and any lateral buds were removed. A plastic ring cut from Tygon tubing was placed over the rootstock and a vertical slit approximately 2 cm made into the rootstock. The V-shaped scion was then placed in the slit and the graft joint secured by positioning the plastic ring over the joint to ensure close contact and immobility between the rootstock and the scion. The grafted plants were kept in an inverted plastic cup to maintain high humidity for 5 days. Seven days after grafting, grafted plants were inoculated with appropriate strains of *A. rabiei.*

Table 1. Disease severity of grafted plants after inoculation with three isolates of *Ascochyta rabiei.*

Rootstock	Scion	Isolates	No. of grafted plants	Reaction to isolate[1]		Disease severity[2]	SD[3]
				Rootstock	Scion		
Dwelley	Spanish White	Control	12	NA	NA	1.0	0
Dwelley	Spanish White	AR19	12	+	-	7.4	0.79
Dwelley	Spanish White	AR20	12	+	_	5.2	1.03
Dwelley	Spanish White	AR628	12	+	-	7.0	1.48
Dwelley	Dwelley	Control	8	NA	NA	1.0	0
Dwelley	Dwelley	AR19	8	+	+	3.0	0
Dwelley	Dwelley	AR20	8	+	+	2.1	0.64
Dwelley	Dwelley	AR628	5	-	-	4.4	1.14
Spanish White	Spanish White	Control	8	NA	NA	1.0	0
Spanish White	Spanish White	AR19	8	-	-	8.1	1.46
Spanish White	Spanish White	AR20	8	-	-	5.8	1.04
Spanish White	Spanish White	AR628	5	-	-	7.0	1.41
Spanish White	Dwelley	Control	12	NA	NA	1.0	0
Spanish White	Dwelley	AR19	12	_	+	3.0	0.43
Spanish White	Dwelley	AR20	12	-	+	2.3	1.30
Spanish White	Dwelley	AR628	12	-	-	5.7	1.37

1. NA = not applicable; - = susceptible reaction; + = resistant reaction.
2. Scored on 1-9 scale.
3. Standard deviation of the mean.

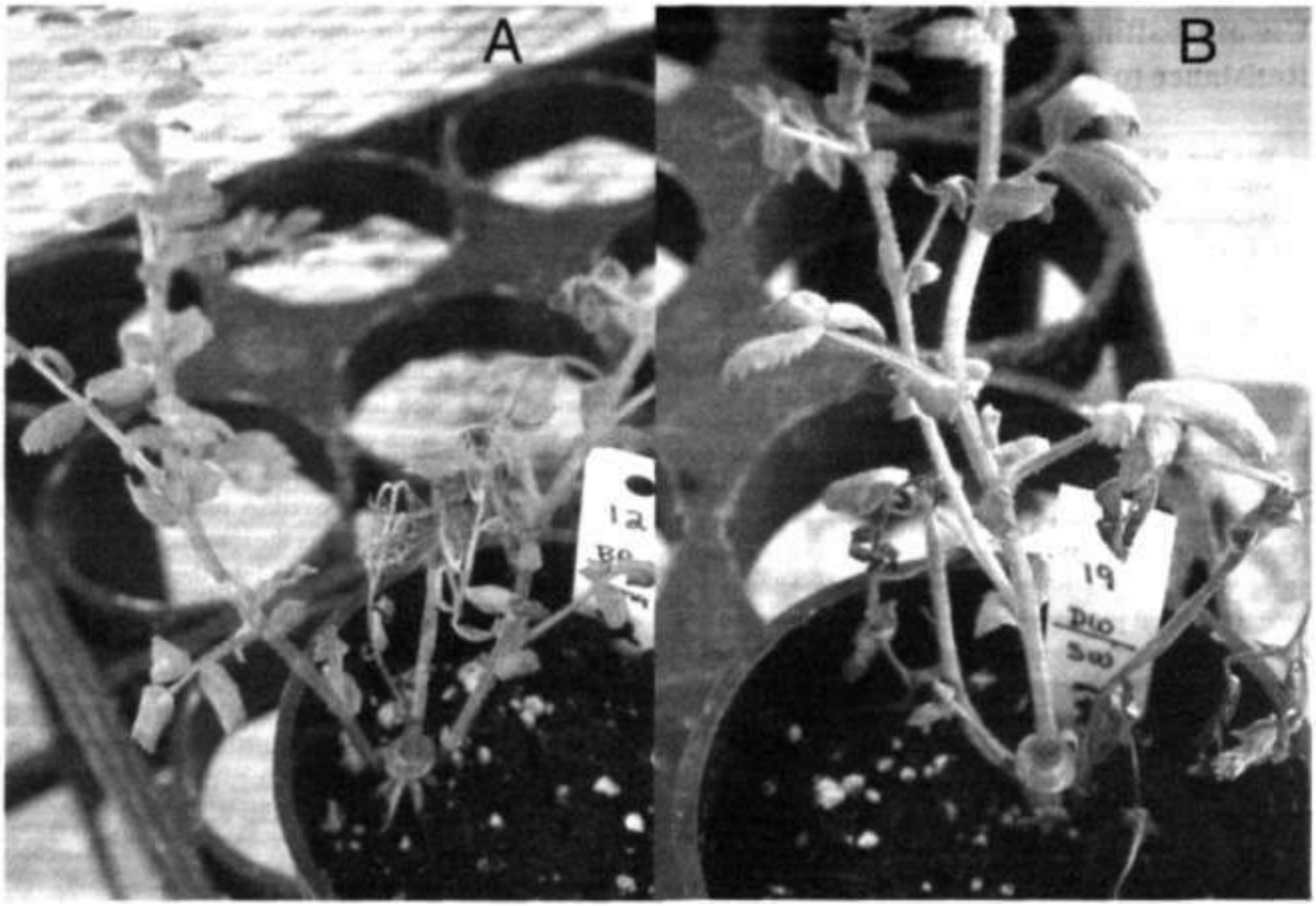

Figure 1. Grafted plants showing differential reactions to inoculation with *Ascochyta rabiei.* [Note: (A) Susceptible scion grafted onto resistant rootstock; (B) Resistant scion grafted onto susceptible rootstock. The plastic ring separating scion from rootstock is visible.]

Two chickpea genotypes, Dwelley and Spanish White (resistant and susceptible to pathotype I of *A. rabiei,* respectively), were used in reciprocal grafting and self-grafting. Three isolates *of A. rabiei,* AR 19 (pathotype I), AR20 (pathotype I) and AR628 (pathotype II), were used to inoculate the plants. The inoculation procedure was the mini-dome technique as described by Chen and Muehlbauer (2003). Fourteen days after inoculation, disease severity was rated using the 1-9 rating scale, which was adopted for seedling bioassays from Reddy and Singh (1984).

Although the lateral buds of the rootstock were removed at the time of grafting, shoots were present on the scion and the rootstock at the time of inoculation and were inoculated in the same manner. Clear differential reactions of the resistant and susceptible genotypes were observed (Fig. 1). Only the reaction of the scion was scored for disease severity. The results of disease scores (Table 1) showed that disease severity ratings varied according to the isolates and the scion genotype. Isolates AR 19 and AR 20 caused high levels of disease severity on Spanish White but low levels of disease severity on Dwelley, whereas isolates AR628 caused high levels of disease severity on both Spanish White and Dwelley. The pattern of disease severity was consistent regardless of the rootstock genotype. When Dwelley scions were grafted onto the susceptible Spanish White rootstock, Dwelley showed higher level of disease severity (5.7 vs 4.4 rating) after inoculation with AR628; however, the difference was not statistically significant. A disease score of 5.7 was typical for natural Dwelley plants after inoculation with isolate AR628. Furthermore, in a repeated grafting experiment, isolate AR628 caused similar high levels of disease severity on Dwelley scions when grafted either on Dwelley or Spanish White rootstocks.

Hamid and Strange (2000) identified a resistance mechanism through glutathione conjugation in chickpea detoxifying phytotoxin solanapyrone A. If the same mechanism operates in Dwelley for resistance to pathotype I isolates, glutathione and/or glutathione S-transferase were not translocated from the Dwelley rootstock to Spanish White scions to an extent to affect the scion's response to infection. Conversely, if there are toxin receptors in Spanish White, the receptor molecules were not translocated from the susceptible Spanish White rootstock to the resistant Dwelley scions to a level to be detectable using the virulence assay. Thus, based on reciprocal grafting between resistant and susceptible chickpea genotypes, the genotype of the rootstock did not affect the disease phenotype of the scion, and disease phenotype was conditioned locally by the scion genotype.

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Entomology

Efficacy of Microbial Bioagents Against *Helicoverpa armigera* on Chickpea

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Chickpea (*Cicer arietinum*) occupies an unique position in pulse crops due to its protein content and wide adaptability as a food grain in the semi-arid tropics, particularly in India. It is grown on an area of 6.9 million ha having a national productivity of 735 kg ha^{-1}. India contributes 80% of the total world production. Sixty insect species are known to attack chickpea, of which the gram pod borer, *Helicoverpa armigera* is the most serious pest causing 30 to 80% damage of the crop in different parts of the country (Asthana et al. 1997). Because of its polyphagous nature and wide geographical spread, it is considered as a noxious global pest. *Helicoverpa armigera* has shown moderate to high levels of resistance to many insecticides. Therefore, we evaluated the bio-efficacy of some promising insect microorganisms, *Bacillus thuringiensis* var *kurstaki* (Btk), *H. armigera* nuclear polyhedrosis virus (HaNPV), *Beauveria bassiana* and native *Steinernema* sp against *H. armigera*, in chickpea during the *rabi* (postrainy) season of 1998/99 and 1999/2000 at the Gujarat Agricultural University, Anand, Gujarat, India.

Chickpea cultivar Dahod Yellow was sown at 30 cm x 10 cm spacing in gross plot of 1.8 m X 2.5 m (net plot 1.2 m X 2.5 m) with four replications in randomized block design (RBD) for two years. All the recommended agronomical practices were followed for raising the crop. The treatments, *Btk* (Delfin WG at 1 kg ha^{-1}), *B. bassiana* (Basina at 1 kg ha^{-1} = 2 X 10^{12} conidia ha^{1}), HaNPV [250 larval equivalent (LE) ha^{-1}], entomopathogenic nematode (EPN) *[Steinernema* sp at 100 million infective juveniles (IJs) ha^{-1}], Neem (Achoock 0.15 EC at 1 L ha^{-1}) and Endosulfan (35 EC at 0.07%) were applied at peak flowering and podding stages when *H. armigera* larvae crossed the economic threshold level (ETL) of 20 larvae/ 20 plants. Spraying was carried out in the evening using a 3-L hand compression sprayer in a sequence as water in control, then EPN, *B. bassiana*, HaNPV, *Btk*, Achook and Endosulfan. In case of laboratory-produced biopesticides (EPN and HaNPV), adjuvants like gum

arabic, Tween-80 and jaggery solution, 2% each, were mixed to reduce desiccation for even coverage and to increase phagostimulant properties. For the marketed biopesticides, formulations were sprayed as such. In each plot five plants were randomly selected and tagged with paper tags and numbered. Observations on *H. armigera* population and mortality were recorded 24 h after spraying and continued every alternate day till 15 days alter the treatment Dead larvae were also collected from sprayed plots and pathogen induced mortality was further confirmed in the laboratory. Chickpea seed yield was recorded at harvest. Data on larval numbers and yield were subjected to appropriate transformation and analyzed individually following RBD and pooled for two years.

Pooled data of two years (1998-2000) showed suppression of larval population due to various treatments from the third day onwards (Table 1). Lowest larval number was recorded in treatment with Delfin (2.31 larvae on five plants). However, larval numbers (on five plants) were similar in treatments with HaNPV (2.86 larvae), Achook (2.99 larvae) and Endosulfan (2.78 larvae). On the fifth day also the larval number (on five plants) was lowest (1.93 larvae) in treatment with Delfin followed by Achook (2.34 larvae) and Endosulfan (2.47 larvae). On the seventh day the larval number (on five plants) was lowest (1.06 larvae) in treatment with Endosulfan followed by Delfin (1.56 larvae). Increase in the larval count was observed from eleventh day onwards (Table 1). No significant differences were observed in all the treatments on fourteenth day though they were significantly better then untreated check. Srinivasan et al. (1994) reported that NPV (250 LE ha^{-1}), *Bt* (1 kg ha^{-1}) and Endosulfan were very effective for suppression of *H. armigera* population on chickpea up to tenth day. Mishra et al. (1991) reported that a single spray of NPV (250 LE ha^{-1}) resulted in 97.2% mortality of *H. armigera.*

Table 1. Efficacy of microbial biopesticides against *Helicoverpa armigera* on chickpea at Anand, Gujarat, India during 1998-2000[1].

Treatment[2]	Number of larvae on five plants							Yield (kg ha^{-1})	Increase (%) in yield over control
	24 h BT[3]	1 day AT[4]	3 days AT	5 days AT	7 days AT	11 days AT	14 days AT		
Delfin	2.76 a (7.62)	2.06 b (4.24)	1.52 d (2.31)	1.39 c (193)	1.25 cd (156)	1.43 b (2.04)	1.57 b (2.47)	1513.89 b	61.48
Basina	2.63 bc (6.92)	2.28 b (5.19)	2.22 b (4.93)	1.76 b (3.10)	1.54 bc (2.37)	1.58 b (2.50)	1.43 b (2.05)	1134.72 bc	21.04
HaNPV	2.53 cd (6.40)	1.93 b (3.72)	1.69 cd (2.86)	1.71 bc (2.92)	1.65 b (2.72)	1.67 b (2.78)	1.56 b (2.43)	1340.28 b	42.96
EPN	2.41 d (5.81)	2.02 b (4.08)	1.93 bc (3.72)	1.73 bc (2.99)	1.69 b (2.85)	1.67 b (2.79)	1.51 b (2.28)	1202.78 bc	28.30
Achook	2.50 cd (6.25)	1.82 b (3.31)	1.73 cd (2.99)	1.53 bc (2.34)	1.53 bc (2.34)	1.65 b (2.72)	1.57 b (2.47)	1326.39 b	41.48
Endosulfan	2.57 bcd (6.60)	1.77 b (3.13)	1.67 cd (2.78)	1.57 bc (2.47)	1.03 d (1.06)	1.29 b (1.66)	1.63 b (2.66)	1784.72 a	90.37
Control	2.73 b (7.45)	2.50 a (6.25)	2.45 a (6.00)	2.17 a (4.71)	2.06 a (4.24)	2.17 a (4.71)	1.95 a (3.80)	937.50 c	-
SEm	0.05	0.22	0.12	0.11	0.10	0.23	0.19	116.02	-
CV (%)	5.81	7.56	10.50	9.06	18.27	16.82	13.31	13.22	-

1. Means followed by same letters do not differ significantly at $P = 0.05$. Figures in parentheses are retransformed values.
2. HaNPV = *Helicoverpa armigera* nuclear polyhedrosis virus; EPN = Entomopathogenic nematode *(Steinernema* sp).
3. BT = Before treatment.
4. AT = After treatment.

All the biopesticides tested effectively suppressed *H. armigera* and gave better chickpea seed yield over control with maximum yield recorded in treatment with Endosulfan followed by Delfin, HaNPV, Achook, EPN and Basina. Btk (Dipel), neem seed extract and Endosulfan were effective in reducing larval population and pod damage resulting in greater yield of chickpea compared to control (Wanjari et al. 1998). Sanap and Pawar (1998) conducted an experiment with sequential application of HaNPV, neem seed kernel extract and Endosulfan against *H. armigera* in chickpea at fortnightly intervals and harvested 26.94% higher yield over control. Low pod damage (6%) and higher yields (2377 kg ha^{-1}) were recorded in chickpea when sprayed with *B. bassiana* at 2.6 x 10^7 spores ml^{-1} (Saxena et al. 1997). Spraying of biopesticides resulted in reduced larval numbers and higher yields in chickpea than control. Therefore, these biopesticides can be effectively combined with other components of integrated pest management for managing this pest in chickpea.

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Pigeonpea

Agronomy/Physiology

Variation in Symbiotic Effectiveness of Four Phage-marked Rhizobial Strains with Different Pigeonpea Cultivars

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The genetic background of both legume host and *Rhizobium* determines the symbiotic performance qualitatively as well as quantitatively (Smith and Goodman 1999). In pigeonpea (*Cajanus cajan*), maturity duration influences nodulation and nitrogen (N) fixation (Kumar Rao and Dart 1987, Rao et al. 1994). Although no thorough study has been conducted to examine the response of pigeonpea cultivars to different rhizobial strains, relative superiority of some cultivar-strain associations cannot be ruled out. This study was carried out to investigate the symbiotic performance of genetically-marked rhizobial strains with pigeonpea cultivars differing in maturity duration.

Out of four rhizobial strains utilized in the study, the strains IHP 195, A039 and A059 were marked by their sensitivity to phages RT-11, RT-2 and RT-5, respectively, while the strain AO25 was lysogenic, liberating phage RT-2 spontaneously in culture and insensitive to any other phage used. The four pigeonpea cultivars, selected on the basis of difference in maturity duration, were MA 3 (265 days), Bahar (250 days), T 21 (165 days) and UPAS 120 (125 days). The plants were raised in earthen pots (13cm height X 10cm top diameter X 6cm base diameter) containing sterilized sand and gravel (3:1). Thornton's plant growth medium (N-free) was used for culture of plants. Bold and healthy pigeonpea seeds were surface sterilized with acidified mercuric chloride (0.2% w/v) for three minutes and then thoroughly rinsed 4-5 times with sterilized distilled water. Two seeds were sown in each pot, which were thinned to one after five days.

Rhizobial inoculation (0.5 ml suspension containing about 10^2 cells) was done two days after sowing. Uninoculated seedlings served as control. Plants were grown in culture room at 26 ± 2°C with 14/10 h light/dark cycle. Sterilized water and Thornton's plant growth medium were applied alternately to support the growth of plants up to 45 days. The experiment was laid out in complete randomized block design with four replications. Data pertaining to symbiotic effectiveness such as nodule number, nodule fresh mass, total plant dry mass, shoot N content and chlorophyll content in leaves were recorded at 45 days after sowing.

The analysis of variance showed significant cultivar X strain interaction with respect to nodule fresh mass, leaf chlorophyll content, total plant dry mass and shoot N content (Table 1). Maximum number of nodules (51) at 45 days was observed in pigeonpea cultivar Bahar in association with strain A025, while maximum nodule fresh mass (225 g) was recorded in the same cultivar with strain IHP 195. Nodule number in MA 3 was the lowest. The pattern of variation in leaf chlorophyll content in different treatments showed that this trait was governed mostly by the genotype of the host legume cultivar and improved due to rhizobial inoculation. The total plant dry

Table 1. Symbiotic effectiveness of different phage-marked rhizobial strains with four cultivars of pigeonpea under controlled environment

Cultivar	Rhizobium strain	Nodule number	Nodule fresh mass (mg plant^{-1})	Leaf chlorophyll content (mg g^{-1})	Total plant dry mass (mg plant^{-1})	Shoot nitrogen content (mg g^{-1})
Bahar	Control	0	0	2.2	600	12.2
	IHP 195	33	225	4.8	1440	20.4
	A059	25	150	4.7	1328	18.8
	A039	28	75	3.4	912	16.8
	A025	51	150	4.1	1040	18.0
MA 3	Control	0	0	2.8	696	12.8
	IHP 195	18	150	4.6	1320	18.4
	A059	16	135	4.7	1392	19.8
	A039	17	165	5.0	1424	21.6
	A025	18	105	4.9	1408	20.6
T21	Control	0	0	2.7	760	13.0
	IHP 195	30	142.5	4.5	1200	17.4
	A059	29	195	4.9	1408	20.2
	A039	24	135	4.2	1152	17.0
	A025	34	157.5	4.8	1280	19.8
UPAS 120	Control	0	0	1.9	624	12.0
	IHP 195	22	120	4.8	1248	19.4
	A059	19	105	4.3	1200	19.2
	A039	15	67.5	3.7	968	16.6
	A025	22	150	4.9	1264	20.0
MSS[1]	Cultivar (C)	1034.25*	6764.06	1.36**	159517**	8.06*
	Strain (Rh)	336.92	11301.56*	15.42**	1184467**	141.68**
	C x Rh	106.92	4626.56*	0.56**	61821**	7.30**
	Error	39.91	1056.71	0.03	1905	0.16
CD at 1%	Cultivar (C)	6.01	30.91	0.153	36.85	0.34
	Strain (Rh)	6.01	30.91	0.172	41.20	0.38
	C x Rh	12.01	61.82	0.343	82.39	0.76

1. MSS = Mean sum of squares; * = Significant at 5% level; ** = Significant at 1% level.

Table 2. Correlation coefficients between symbiotic parameters in pigeonpea x *Rhizobium* interaction under exenic culture condition[1].

Symbiotic parameters	Nodule fresh mass (mg)	Leaf chlorophyll content (mg g^{-1})	Total plant dry mass (mg $plant^{-1}$)	Shoot nitrogen content (mg g^{-1})
Nodule number	0.385	-0.139	-0.239	-0.154
Nodule fresh mass (mg)		0.667**	0.689**	0.560*
Leaf chlorophyll content (mg g^{-1})			0.929**	0.858**
Total plant dry mass (mg)				0.856**

1. Data from uninoculated control was not included in analysis. * = Significant at 5% level; ** = Significant at 1% level.

mass increased by 140%, 105%, 85% and 103% in Bahar, MA 3, T 21 and UPAS 120, respectively due to inoculation with their most compatible rhizobial strains over uninoculated control. On an average, 52% increase in shoot N content was observed due to rhizobial inoculation.

The number of nodules formed did not bear significant correlation with any other character (Table 2). However, nodule fresh mass exhibited significant association with leaf chlorophyll content, plant dry mass and shoot N content. Leaf chlorophyll content had significant association with plant dry weight and shoot N content. Increase in plant dry mass was also associated with increase in shoot N content.

Our study indicated existence of considerable host cultivar specificity of the rhizobial strains under exenic culture conditions. A single rhizobial strain is not highly effective with all the pigeonpea cultivars. The strains IHP 195, A039, A059 and A025 exhibited maximum symbiotic effectiveness with cultivars Bahar, MA 3, T 21 and UPAS 120, respectively as evidenced from the data on nodule mass, leaf chlorophyll content, plant dry mass and shoot N content. However, IHP 195 superseded the remaining three test strains in overall nodule fresh mass and dry matter accumulation followed by A059. Nodule number was found to be a less reliable indicator of strain effectiveness that has also been reported in legume crops in general (Somasegaran and Hoben 1994). Although our investigation was on cultivars differing in maturity duration, similar variation among varieties within one maturity group may also be found.

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Adaptation of Pigeonpea in the Mediterranean Coast of Turkey

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Although more than 40 food legume species are cultivated in the world (Toker 2003), some of these are neglected crop plants in some regions. Pigeonpea (*Cajanus cajan)* is one of the common pulses in Southeast Asia. World production of pigeonpea is approximately 3 million t produced on an area of 4 million ha. However, statistics for pigeonpea in Turkey are not available (FAO 2002). van der Maesen (1990) has given some vernacular names of pigeonpea. Pigeonpea is known as *giivercin bezelyesi* or *hint bezelyesi* in Turkish (Toker 2003). To our knowledge, this is the first report on growing of pigeonpea in Turkey.

Five pigeonpea genotypes, ICP 7035, ICP 8863, ICPL 87, ICPL 87051 and ICPL 88039, from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India were sown in the third week of April 2001 in Antalya, Turkey. The experiment was conducted for two years in a randomized complete

Table 1. Performance of pigeonpea genotypes in Antalya, Turkey.

Genotype	Days to flowering	Days to maturity	Plant height (cm)	Pod length (cm)	Pod width (cm)	Seed yield (kg ha^{-1})	100-seed mass(g)
ICPL 87	135	212	99	4.15	0.50	491	9
ICP 7035	343	416	195	6.37	1.17	389	17
ICPL 87051	357	430	191	6.33	0.83	540	11
ICPL 88039	93	174	127	4.83	0.73	993	13
ICP 8863	364	437	183	5.10	0.57	368	7
Grand mean	258.3	333.8	159.1	5.39	0.76	556.3	10.8
LSD	2.38	1.26	14.98	0.36	0.29	330.64	0.52
CV (%)	0.49	0.20	5.00	3.53	20.31	31.57	2.59

block design with three replications. The experimental plots consisted of four rows of 6 m length with row spacing of 75 cm and plant spacing of 25 cm. Sowing was done by hand. Soil was fertilized with ammonium nitrate applied at 20 kg nitrogen (N) ha^{-1}. Hand weeding was done during seedling stage. Sprinkler irrigation was used at the time of germination. After seedling stage, no irrigation was provided and the plants were grown under rainfed conditions. Plants were exposed to drought and high temperature stresses.

Organic matter and macronutrients were found at low levels with 0.1% total N in the experimental area. Soil was loamy having pH 8.05 and 30.76% calcium carbonate. Generally rainfall was irregular and insufficient during title growing seasons. The maximum temperature rose up to 43.3℃ in August 2001 and minimum temperature of 0℃ was recorded in December 2002.

Analysis of variance of data revealed that genotypes were significant for days to flowering, days to maturity, plant height, pod number plant^{1}, pod length, pod width, seed mass and flowering duration over two years *(P<0.01*). Of the five genotypes, ICPL 88039 flowered first in 93 days and matured in 174 days after sowing (Table 1). Plant height ranged from 99 cm in ICPL 87 to 195 cm in ICP 7035. ICP 7035 had 6 flowers per peduncle. However, pod number was equal in all the genotypes with 3 pods peduncle^{1}. Pod length of the genotypes ranged from 4.15 to 6.37 cm while pod width was between 0.5 and 1.17 cm (Table 1). ICPL 87 and ICP 8863 had 3 seeds pod^{-1} whereas the remaining genotypes had 4 seeds pod^{-1}. The seed yield of the genotypes ranged from 368 to 993 kg ha^{-1} (Table 1).

Seed yield of the genotypes is lower than previously reported (Chauhan 1990). The low yield could be due to drought and high temperature effects as well as plant density, van der Maesen (1992) reported that the seed yield of pigeonpea under optimum conditions could be more than 5000 kg ha^{-1}. The results of our study were in agreement with findings of Remanandan et al. (1988) except for days to flowering because three genotypes, ICP 7035, ICPL 87051 and ICP 8863, flowered in the second year. Seed yield of ICPL 88039 was more than average world seed yield of pigeonpea; hence, this genotype could successfully be grown as an alternative food legume under rainfed conditions in the Mediterranean coast of Turkey.

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Pigeonpea Sterility Mosaic Disease: An Emerging Problem in Northern Karnataka, India

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In Karnataka, India pigeonpea *(Cajanus cajan)* is currently grown on 0.49 million ha with a production of 0.26 million t. Gulbarga, Bidar, Bijapur, Raichur and Koppal districts in the northern region contribute to 82% of the total pigeonpea production in Karnataka. This region is popularly known as the pigeonpea bowl. Pigeonpea is cultivated as a rainfed sole crop or intercropped with pearl millet *(Pennisetum glaucum),* sorghum *(Sorghum bicolor),* sesame *(Sesamum indicum),* black gram *(Vigna mungo),* mung bean *(Vigna radiata)* and soybean *(Glycine max).* It is grown for grain, which is sold in local markets for cash. Several dhal (dehulled pigeonpea seed) mills are located in this region for dehulling and processed seed is exported to other parts of India.

A shift towards extensive pigeonpea cultivation in this region started over 40 years ago. Earlier, cotton *(Gossypium* sp) and groundnut *(Arachis hypogaea)* were the major crops. Due to erratic rainfall and the scarcity of water for irrigation, yields of these crops were reduced significantly. Under similar conditions, pigeonpea, cultivated then as a minor crop, thrived; consequently, its cropping area gradually increased. Presently, it occupies a major part of the agricultural land in this region and is the chief income source contributing to the livelihoods of farmers. However, pigeonpea production in this region is not stable due to fusarium wilt and pod borer *(Helicoverpa armigera).* In addition, sterility mosaic disease (SMD), once a minor or non-existent problem on pigeonpea in these regions, is emerging into a major problem (Narayana et al. 2000). The disease is caused by the pigeonpea sterility mosaic virus (PPSMV) transmitted by the eriophyid mite *Aceria cajani.*

A few decades ago, high-yielding pigeonpea varieties GS-1 and PT-221 were popularly grown. But these varieties were highly susceptible to wilt and threatened the future of pigeonpea cultivation in these regions. The University of Agricultural Sciences (UAS), Dharwad, Karnataka released the pigeonpea variety ICP 8863 as Maruti in 1986. This variety is highly resistant to fusarium wilt and was selected from germplasm of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. Because of its resistance to wilt and high yield potential, Maruti has become popular among farmers. Presently this variety occupies about 70% of the total pigeonpea cropping area in northern Karnataka (Bantilan and Joshi 1996). However, Maruti is highly susceptible to SMD. During initial years of cultivation, SMD appeared in traces in some areas in Bidar district, bordering Maharastra state. The disease incidence increased in this region following a major SMD epidemic in 1990 in the adjoining Marathwada region of Maharashtra (Zote et al. 1997). Because of the extensive

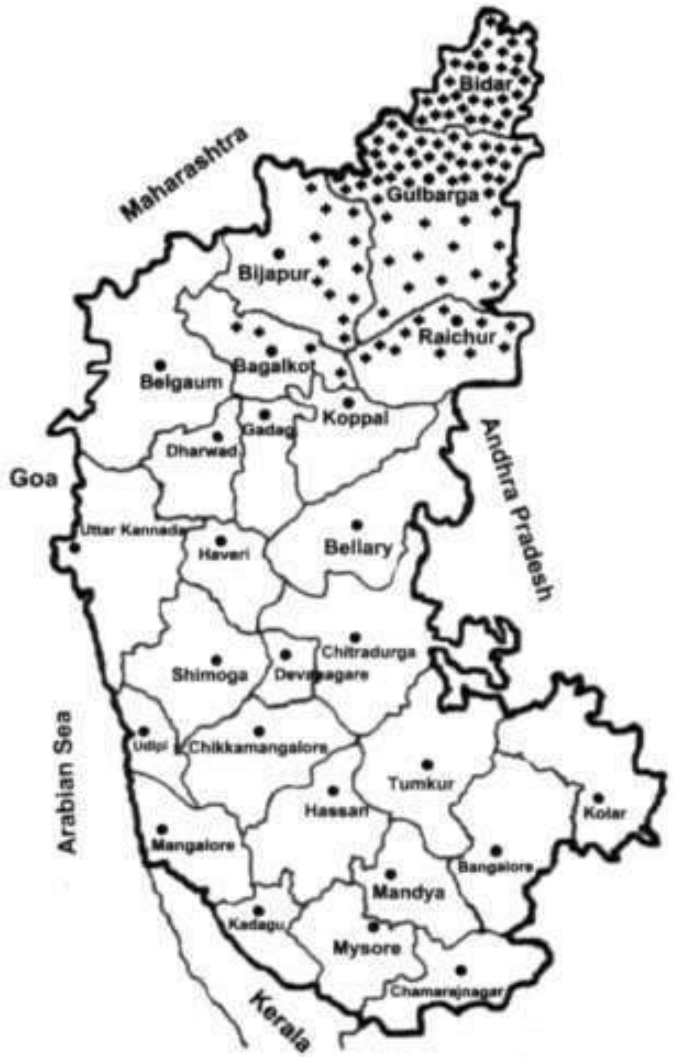

Figure 1. Sterility mosaic disease-endemic areas (*) in northern Karnataka, India.

and continuous cultivation of Maruti as sole crop over larger area, SMD from these minor patches spread over to wider regions in Bidar and Gulbarga, and began to spread to other pigeonpea-growing regions in northern Karnataka (Fig. 1). Since then, increased SMD incidence was reported year after year in these regions (Table 1). Surveys during the *kharif* (rainy) season in 1997 indicated severe incidence of SMD in Bidar and in few taluks of Gulbarga district (Narayana et al. 2000). During the past 8 years, 30-60% SMD incidence was recorded in several farmers' fields and in some farms 100% incidence was recorded (Officers of Karnataka State Department of Agriculture, personal communication).

One of the reasons for increased epidemics of SMD in recent years could be due to the continuous cultivation of SMD-susceptible varieties over large areas, as a sole crop year after year in the same fields. The practice of leaving stubble (30-60 cm height above ground surface) after harvesting the crop in the field allows new flushes of growth, especially in plants under the shade of sugarcane *(Saccharum officinarum)* fields and near irrigation channels. Such plants support mite multiplication and serve as volunteer inoculum sources for new pigeonpea crop sown the following season. Moreover, SMD-affected plants attract little attention from farmers, as the plants show normal vegetative growth pattern. Only at the time of flowering do farmers realize that the crop fails to produce any flowers. There were several incidents of farmers resorting to chemical sprays to induce flowering. Where partial or late infections occur, plants produce some flowers but the seed from such plants is shriveled, poor in quality and fetches a low price. About 20% (worth over US$11 million per annum) of the gross pigeonpea production in this area is lost due to SMD.

Attempts are being made to develop high-yielding varieties possessing resistance to both SMD and wilt. In 2000, an ICRISAT-bred pigeonpea variety ICPL 87119 was released as Asha for cultivation in these areas. Asha is resistant to wilt and the SMD strain prevalent in northern Karnataka, but it is late in maturity (190-200 days). Hence, the crop is predisposed to terminal drought and increased pod borer attacks. Despite this, the variety is recommended for cultivation with appropriate crop management practices in SMD-endemic zones. Training programs are being organized to educate farmers in integrated management of wilt, SMD and pod borer. The development of multiple disease resistant pigeonpea varieties, with a maturity period of 160-170 days is required for this region.

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Table 1. Pigeonpea sterility mosaic disease (SMD) incidence in northern districts of Karnataka, India during 2000/01 and 2001/02[1].

District/Taluk	Area surveyed (ha)	SMD incidence (%)		
		2000/01	2000/02	Mean
Gulbarga				
Gulbarga	766	20.5	24.2	22.35
Aland	322	12.0	40.9	26.45
Chincholi	161	48.0	58.2	53.10
Afzalpur	129	12.0	14.1	13.05
Mean	344.5	23.12	34.35	28.73
Bidar				
Humnabad	242	42.0	53.2	47.60
Bhalki	161	48.0	56.5	52.25
Bidar	262	52.2	60.3	56.25
Basavakalyan	153	40.3	42.3	41.30
Mean	204.5	45.6	53.0	49.35

1. SMD incidence was based on symptoms. Random samples were tested for PPSMV by double antibody sandwich ELISA as described by Kumar et al. (2002) (data not shown). Nearly 80% of the surveyed field contained the variety Maruti; rest were local varieties (cultivar information unknown).

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Utilization

Utilization of Pigeonpea Seeds as Protein Supplement in Chicken Ration

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Feeds are often the single largest operating cost item in broiler production and about 75% of the business budget is allocated to feed supply. Reducing such costs would mean greater income and savings to producers.

The requirement of protein in animal feed cannot be met with the present status of soybean (*Glycine max*) production in the Philippines (Bureau of Agricultural Statistics 1996). In concentrate diets, the main source of protein is soybean, which has to be imported. This situation drains the country's economy. Therefore, the country is aiming to meet its protein requirement in animal diets from indigenous crops such as pigeonpea *(Cajanus Cajan).*

In the Philippines, pigeonpea is a well adapted crop in marginal areas and the seed contains on an average 20.5% crude protein and 5.0% crude fiber (Bureau of Plant Industry 1996). This can be included safely in broiler chicken diets at a level up to 30% with no significant depression in live weight gains (Nambi and Gomex 1983). The low levels of cystine, tryptophan and phenyl alanine restrict inclusion at higher levels (Springhall et al. 1974, Wallis et al. 1986). However, this problem can be overcome by including other legumes that are rich in cystine and tryptophan. To utilize pigeonpea which is very well adapted in the region, a research study was conducted to determine the most acceptable level of pigeonpea seeds to be mixed with the pure commercial feeds for broilers.

Ninety-six 2-week-old broiler chicks were studied in a randomized complete block design with four levels of pigeopea seed meal (PSM) and pure commercial mash (PCM) as treatments. The levels (PSM:PCM) were T_1 - 0:100, T_2 - 15:85, T_3 - 30:70 and T_4 - 45:55. Each treatment had eight birds and was replicated three times. The birds were fed ad libitum with the mixed ration and the feeding period was for 4 weeks from 5 December 1995 to 2 January 1996.

Protein content was slightly lower in the test rations supplemented with PSM when compared to PCM. The total crude protein was 21% in T_1, 20.4% in T_2, 20% in T_3 and 19.6% in T_4 (Table 1). Total gain and daily gain in body weight of the bird differed significantly ($P<0.05$) in

different treatments. The body weight of broilers did not differ significantly with 15 to 30% PSM supplementation compared to PCM. Body weight was low with 45% PSM supplementation in ration. Daily gain in body weight was greater in 15% PSM ration compared to higher levels of PSM supplementation. Feed consumption was not affected significantly ($P>0.05$) by the different levels of PSM supplementation. However, birds fed with 45% PSM supplementation consumed more feed (3.68 kg) and those fed with 30% PSM supplementation consumed less feed (3.34 kg). The feed conversion efficiency in birds fed with a ration of 15% PSM plus 85% PCM was better but comparable with birds fed with 30% PSM plus 70% PCM and 0% PSM plus 100% PCM rations. The weight of dressed chicken and giblets and dressing percentage were not affected when broilers were fed with different levels of PSM in the ration. The carcass of birds fed with 15% PSM plus 85% PCM ration was of a high quality. The meat was very tasty, delicious, odorless, smooth, soft, and had a very good flavor. In effect, birds fed with 15% PSM plus 85% PCM registered the lowest production cost (Php 38.88 kg^{-1}) with highest income (Php 11.12 kg^{-1}).

Our study indicated that birds fed with 15% PSM plus 85% PCM had high body weight and daily gain in body weight, were more efficient in feed conversion and had good acceptable carcass quality. This level, however, was comparable with the 30% PSM and 70% PCM supplementation. These findings conformed with treatments reported by Springhall et al. (1974) that pigeonpea seed

Table 1. Performance of pigeonpea seed meal (PSM) as supplemental feed in broiler production at the Mariano Marcos State University, Philippines during 1996.

Parameters	Pure commercial mash (PCM)	15% PSM + 85% PCM	30% PSM + 70% PCM	45% PSM + 55% PCM	CV (%)
Crude protein (%)					
Broiler starter mash (BSM)	21	17.8	14.7	11.6	
Pigeonpea seed meal (PSM)	0	2.6	5.3	8.0	
Total protein (%)	21	20.4	20.0	19.6	
Final weight of birds[1] (kg)	1.6 a	1.6 a	1.6 a	1.5 b	2.6
Gain in body weight[1] (kg)	1.3 a	1.3 a	1.2 b	1.1 c	3.5
Daily gain in body weight[1] (g)	30.1 b	30.5 a	29.6 c	27.3 d	3.5
Feed consumption (kg)	3.6	3.4	3.3	3.7	7.3
Feed efficiency ratio[1]	2.9 a	2.6 a	2.7 a	3.2 b	4.6
Quality of carcass[2]	Meat fairly soft, non-fatty, tasty and delicious but with odor	Meat smooth and soft, highly fatty, very tasty and delicious, good flavor and odorless	Meat fairly smooth and soft, tasty and delicious, fatty, good flavor and odorless	Meat somewhat rough, fatty, tasty and delicious but with odor	
Production cost (Php)	6345.00	6264.20	6287.90	6642.20	
Gross income[3] (Php)	7965.00	8055.00	7870.00	7385.00	
Net profit (Php)	1620.00	1790.80	1582.10	742.80	
Profit over PCM (Php)	-	170.80	-37.90	-877.20	
Production cost (Php kg^{-1})	39.83	38.88	39.94	44.97	
Income (Php kg^{-1})	10.17	11.12	10.05	5.03	

1. Means followed by the same letter did not differ significantly at 5% level using the Duncan's Multiple Range Test.
2. One bird per treatment per replication was evaluated by 30 individuals.
3. At Php 50.00 kg^{-1} (US$1 = Php 27.00).

could be included safely in broiler diets at levels up to 30% with no significant depression in live weight gains.

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Publications from ICRISAT

Pande S, Bourai VA, Neupaoe RK and **Joshi PK. 2003.** Chickpea production constraints and promotion of integrated pest management in Nepal. On-farm IPM of Chickpea in Nepal-l. Information Bulletin no. 64. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 32 pp. ISBN 92-9066-462-2. Order code IBE064. HDC US$21.00, LDC US$7.00, India Rs 329.00.

Chickpea production in Nepal drastically came down to 19,000 ha in 1997/98 from 54,000 ha in 1981/82. This was mainly due to biotic and abiotic stresses. To overcome these drawbacks and address the plight of chickpea producers, ICRISAT and NRI in collaboration with NARC launched an aggressive program. To diagnose chickpea production environment at micro level, the entire hillside-Terai region of Nepal was selected for the study. In all, 500 chickpea producers were selected for the study. It was found that rotation of chickpea cuts down the use of chemical fertilizers and also enhances the output of paddy significantly. If the joint mission of ICRISAT/NARC with the IPM package overcomes biotic and abiotic constraints then it will enhance the socioeconomic life of chickpea farmers in Nepal.

Pande S, Bourai VA, Stevenson PC and **Neupane RK. 2003.** Empowerment through enrichment. IPM of chickpea in Nepal-2. Information Bulletin no. 65. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 28 pp. ISBN 92-9066-463-0. Order code IBE065. HDC US$ 18.00, LDC US$6.00, India Rs 282.00.

"Empowerment Through Enrichment" is the second information bulletin and is part of the project 'IPM of chickpea in Nepal'. It contains information about the mid-term evaluation of the project. This is in continuation of the first study "Chickpea Production Constraints and Promotion of Integrated Pest Management in Nepal". The mid-term evaluation revealed that the success of adoption of IPM technology was due to socioeconomic emancipation of peasants, freedom from the clutches of usurpers and poorest among the poor being benefited. Market linkage strengthened farmer's faith in technologies. Since chickpea is highly remunerative as a crop of rice fallow lands in winter *(rabi)*, the technology is fast spreading to other villages. Sustainable environment will make the intervention spread faster.

Pande S, Bourai VA and **Neupane RK.** 2003. Wealth generation through chickpea revolution. IPM of chickpea in Nepal-3. Information Bulletin no. 66. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 36 pp. ISBN 92-9066-464-9. Order code IBE066. HDC US$ 24.00, LDC US$8.00, India Rs 376.00.

The IPM of chickpea project is a sustainable development model implemented by lCRISAT/NARC in Nepal. The model brought about a positive affect on soil, income and health of people living below the poverty line. The four districts selected for the study are situated in central and midwestern hillside-Terai regions in Nepal. The study was conducted with the help of PRA techniques. The results show that IPM of chickpea brought about a revolution in the study villages. The empirical study of IPM of chickpea package including cultivars has shown that technology is an effective remedy for eradication of hunger in Nepal Terai. Starvation can be prevented by systematically recreating a minimum level of income and entitlements for those hit by changed agricultural economies in Nepal. The overall income of farmers increased from regeneration of chickpea crop and also improved soil health. The project succeeded in bringing about a change in the status of village women who are major players in the agriculture sector of Nepal. Intensification of the project in the Terai will change the entire livelihood pattern of poor peasants for better. This model can be applied elsewhere in the world, where similar agro-ecological features are available, for alleviation of poverty.

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Chickpea Publications

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Notes

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The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political, international organization for science-based agricultural development. ICRISAT conducts research on sorghum, pearl millet, chickpea, pigeonpea and groundnut - crops that support the livelihoods of the poorest of the poor in the semi-arid tropics encompassing 48 countries. ICRISAT also shares information and knowledge through capacity building, publications and ICTs. Established in 1972. it is one of 15 Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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