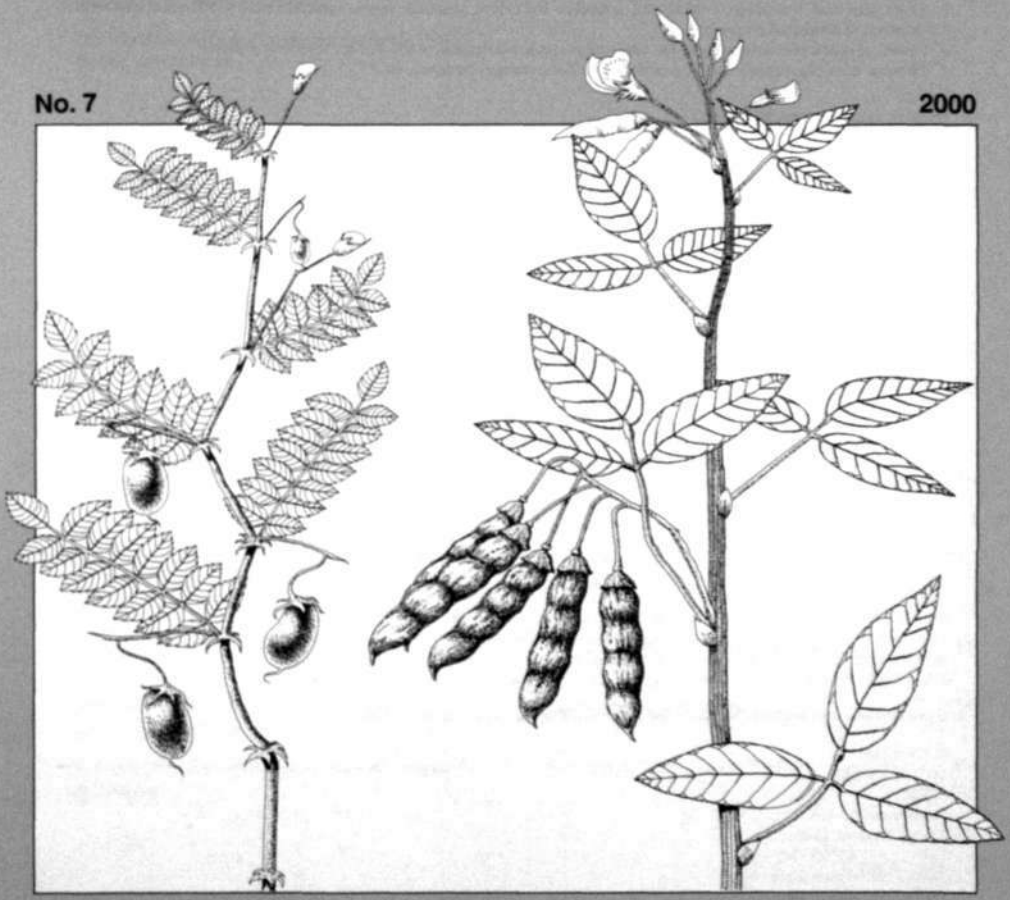
International Chickpea and Pigeonpea Newsletter

No. 7 2000



International Chickpea and Pigeonpea Newsletter

Publishing objectives

The International Chickpea and Pigeonpea Newsletter (ICPN) is published annually by ICRISAT. It is intended as a worldwide communication link for all those who are interested in the research and development of chickpea (*Cicer arietinum* L.), and pigeonpea [*Cajanus cajan* (L.) Millsp.], and their wild relatives. Though the contributions that appear in ICPN are peer-reviewed and edited, it is expected that the work reported will be developed further and formally published later in refereed journals. It is assumed that contributions in ICPN will not be cited unless no alternative reference is available.
ICPN welcomes short contributions (not exceeding 600 words) about matters of interest to its readers.

What to contribute?

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

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

How to format contributions?

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

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

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

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Contents

From the Editor

We have pleasure in presenting the seventh issue of ICPN. This comes at a time when we as researchers are being increasingly challenged to demonstrate impact from our work on the livelihoods of the poor in the semi-arid tropics (SAT). Anybody associated with these two crops hardly needs to be convinced of the important role that they play, but we need to be far more proactive in getting this message across to policy makers and potential investors. ICRISAT is in the process of producing The World Chickpea and Pigeonpea Economy: Facts, Trends and Outlook which is designed to assist in this process and help researchers from all disciplines focus on the priority problems that need to be addressed. We would welcome contributions on how chickpea and pigeonpea are contributing to the livelihoods of the poor, and opportunities that exist to target new markets.

The editors would like to thank the following people for their time in reviewing articles in the current issue of ICPN: C Johansen, D D R Reddy (ANGRAU), E M Minja, G V Ranga Rao, H C Sharma, Jagdish Kumar, K K Sharma, L Krishnamurthy, N P Saxena, N Seetharama, S D Singh, Suresh Pande, S P Wani, S Sivaramakrishnan, Y S Chauhan, and S Chandra. We also thank the contribution of Library and Documentation Services, ICRISAT for compiling the SATCRIS listing as well as verifying the references in the Research Reports.

Said N Silim
Richard B Jones

News

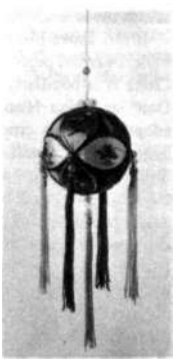
Chinese Award to ICRISAT Scientists

We are proud to announce that two of our scientists, Drs L J Reddy and K B Saxena of Genetic Resources and Enhancement Program (GREP), were awarded the Jin Xiu Qiu Jiang (Golden Love Ball) award for 1999 by the Guangxi Provincial Government of China for their contributions to research and development of pigeonpea in the Guangxi province of south China.

L J Reddy

K B Saxena

ICRISAT and China have been cooperating on pigeonpea research and development in Guangxi for the past three years. Drs Reddy and Saxena provided improved varieties, exchanged research information, and helped train Chinese scientists and government staff during this period. The Golden Love Ball (very similar to the picture) is a traditional folk symbol of love and friendship. The tradition has gradually been extended to express the highest appreciation to foreign scientists who have contributed significantly to research and development in Guangxi.



The 1999 award was given to four foreign scientists, one from Brazil and three from India (two of whom are from ICRISAT) by the Bureau for Foreign Experts, Guangxi Zhuang Zhu Autonomous Region, on 7 January, during their Science and Technology Activity Week of 2000,

and was presented in absentia to our scientists. In their letter to Dr William D Dar, Director General, ICRISAT, announcing the award, Prof Zong Xuxiao, CLAN Coordinator, China, and Ms Yang Shiying, Leader of the Legume Program, ICGR, GAAS, Guangxi Province, say

"... we feel that the introduction of pigeonpea in China will help farmers in improving their quality of life. On behalf of our government, we thank ICRISA T for supporting this program. Congratulations to you and to your outstanding scientists ".

ICRISAT Pigeonpea Jumps Over the Himalayas

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is an important legume component in the dryland agricultural production systems, mainly because of its ability to produce large amount of high quality biomass and protein-rich seeds. India is the largest producer of pigeonpea, accounting for over 80% of the world production. Other important pigeonpea growing countries are located in South America as well as in southern and eastern Africa. In Asia besides India, Nepal and Myanmar grow considerable acreage of pigeonpea. The newly bred ICRISAT varieties have taken pigeonpea crop into new areas. The latest example is the success of our varieties across the Himalayan range in China.

It was about 1500 years ago when some adventurous traders carried pigeonpea seeds from India to China. In China it is popularly known as "Mu Dou" or "San Ye Dou" or "Qian Nian Dou" or "Shu Huan Dou". The adoption of this crop failed in the country due to its long-duration, small seeds, low yield, and bitter taste. Still the crop managed to survive for centuries because the local people discovered the folk medicinal values of pigeonpea. In 1950s, the Chinese scientists successfully explored the possibility of raring a beneficial insect *(Kerria lacca* Kerr.) for the production of lac, a commercial resin produced by larvae which is deposited along the main stem and branches. Although the cultivation of pigeonpea in China has ceased due to loss of international lac market, the landraces have been preserved in the backyards of the farmers and in the forest lands.

In 1997, the first set of newly developed ICRISAT pigeonpea varieties was sent to China. These varieties were found to have high adaptability in different agro-ecological zones of southern China. Besides high seed yield potential, these varieties matured early, had resistance to diseases and contained good quality seeds suitable for dry and green (vegetable) purposes. Some genotypes were also found to have additional character of high biomass production.

Considering the performance of ICRISAT's genetic materials in 1997 and 1998, with respect to their adaptation in the dry and degraded soils and their ability to produce quality fodder, a team of Chinese scientists including Li Zhenghong, Lu Fuji, Li Kung, and Zhou Chaohong in Yunan Province decided to grow this crop for soil conservation and rehabilitation of degraded and eroded soils. A research and development program was organized by the Institute of Resources Insect of the Chinese Academy of Forestry in Kunming. The scientists at this institute, including Zhang Jianyun and Gu Yong, are also conducting experiments to find out alternate uses of pigeonpea seeds.

Guangxi Academy of Agricultural Sciences (GAAS) is cooperating with Chinese Academy of Agriculture Sciences (CAAS), has taken up the challenge of promoting pigeonpea in more than a dozen hilly counties. The agricultural land in these counties is poor due to frequent land slides and floods. Each year large areas are left fallow because a suitable crop which could grow in these harsh environments is not available. The trials conducted with ICRISAT pigeonpea materials have given a hope to green the barren lands of the province. The tender leaves and branches of young pigeonpea plants make a good fodder. The team of GAAS scientists consisting of Yang Shiying, Li Yangrui, Wei Dakai, Chen Chengbin and other country workers have conducted successful grazing and stall-feeding trials. Both goats and cattle relish its fodder. A large seed production program of ICRISAT lines has been undertaken at the experimental farm of GAAS in Nanning.

Mr Zong Xuxiao, an Associate Professor at the Institute of Crop Germplam Resources (ICGR) of the Chinese Academy of Agriculture Sciences (CAAS) in Beijing, and Coordinator of pigeonpea promotional activities with ICRISAT together with Mr Hu Jiapeng and Xie Jinsui, has also taken up the challenge of promoting pigeonpea cultivation in other provinces such as Jiangxi, Guizhou and Hainan. They are also visualizing a potential market of vegetable pigeonpea in Beijing.

To develop a long-term sustainable pigeonpea production program, the Chinese Government sought further support from ICRISAT for transferring scientific knowledge and new materials. ICRISAT quickly responded by sending three pigeonpea experts to China and by arranging a two-month long training program for four Chinese

scientists at ICR1SAT. These scientists not only received training in various scientific fields but also were given opportunity to see how commercial pigeonpeas are grown, processed and marketed in India. About 1 t seed of ICRISAT variety ICPL 87119 is being sent to Nanning for conducting large-scale on-farm trials during 2000.

The active scientific partnership between ICRISAT and China has shown very encouraging results. Now pigeonpea crop can be seen growing on the road sides and slopy river banks (see figure above). We believe that a good beginning has been made and the ties between ICRISAT and China will be strengthened further. A search for financial assistance has begun to execute this endeavour for the noble cause of helping the dryland farmers of southern China.

Contributed by: K B Saxena, ICRISAT; Zong Xuxiao, CAAS, Beijing, China; Yang Shiying, GAAS, Nanning, China; Li Zhenghong and Zhou Chaohong, IRI, Kunming, China.

(For more information contact: Dr K B Saxena, ICRISAT, Patancheru 502 324, Andhra Pradesh, India; email: k.saxena@cgiar.org)

Pigeonpea Day in South Africa

Pigeonpea *dhal*, locally called as *'oil dhal'*, is a favorite *dhal* of Indian migrant community in South Africa. To meet their demand about 2000-2500 tonnes of *dhal* is imported each year. Since last few years researchers in South Africa are trying to promote pigeonpea in dry areas with technical support from ICRISAT. The initial adaptive trials were very successful. On 25-26 May, Mr Cherian Mathews and Mr Mark Anthony of Lowveld Research Unit, Department of Agriculture, Conservation and Environment, Nelspruit, organized a successful 'Pigeonpea

(L to R) Dr R B Jones (Pigeonpea Technology Exchange Specialist), ICRISAT-Kenya; Mr S Maluleka (Chief Director, Professional Services) DACE, Mpumalanga; Mr J E Volschenk (Chief Director, Regional Services) DACE, Mpumalanga; Dr K B Saxena (Senior Pigeonpea Breeder) ICRISAT-India; and Mr C Mathews (Specialist Scientist), DACE, Mpumalanga.

Dr K B Saxena with the pigeonpea interest group (farmers and extension officers) during a field visit to pigeonpea trial plot at Malekutu, 25 May 2000.

Day' at Mpumalanga. On the first day "Farmers' Field Day", attended by about 40 farmers, was organized and the on-farm demonstrations were shown. On 26 May, a meeting of 'Pigeonpea Interest Group' was held which was attended by over 50 participants representing various agriculture research centers and NGOs. Mr J E Volschenk, Chief Director, Regional Services, presided over this meeting and expressed hope that ICRISAT support will help in developing their pigeonpea research and development program in South Africa in the near future. In a key development a "Network for Pigeonpea Research and Development" was formed and Mr Mathews was elected its Coordinator. ICRISAT was represented by Drs K B Saxena and R B Jones.

Views

Monograph of *Dunbaria* Available

ICRISAT has acquired wild relatives of its mandate crops through collection in areas of occurrence. As such, collections of *Dunbaria* as a genus related to *Cajanus* have been present since the 1970s. Although the numbers of living accessions are not very large, the availability of some species enables research into them. The prime source of information lies in the herbarium collections of the areas where the species occur or did occur. Until 1998, no modern revision was available, but finally the fruits of my research were published as Wageningen Agricultural University Papers 98-1: Revision of the genus Dunbaria Wight & Arn. (Leguminosae-Papilionoideae) 109 pp.

For this investigation the herbarium collections of 33 herbaria were studied, most of them have been in Wageningen for an extended period of time. All specimens have been returned to their owners in the meantime, properly labeled with their correct scientific name.

The monograph describes 20 species of *Dunbaria,* one of the genera in the subtribe Cajaninae of the legu-"minous tribe Phaseoleae, to which *Cajanus* also belongs. One species, the rare *D. floresiana,* was described as new to science, and six species were provided with a new combination. Most *Dunbaria* species are distributed in Asia, while some species are found in Australia and New Guinea (see Appendix for *Dunbaria* collections available at ICRISAT, seeds for which, can be directly obtained from Genebank Curator, ICRISAT). All species are climbers with the general appearance of beans, and grow in semi-deciduous forests, scrub vegetation or grasslands of the moist or semi-arid tropical habitats. From Vietnam to Japan one possibly cold-resistant species, *Dunbaria villosa,* is found somewhat outside the range of the rest of the genus. *Dunbaria* may play a role in breeding, as it belongs to the secondary genepool of the pigeonpea, to which it is obviously related, if we judge from morphological appearance. Genetic relationships have not been investigated in detail, and cytological data have not come to my attention. Crossings have been attempted in ICRISAT, but results have not been published.

Some free copies of the monograph are available to bona-fide pulse scientists. Please write or e-mail at the following address:

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PO Box 8010, 6700 ED Wageningen, the Netherlands
e-mail:jos.vandermaesen@algem.pt.wau.nl

Appendix. Details of *Dunbaria* species available with ICRISAT Genebank, Patancheru.

ICP No.	Collector's number	Species name	Province	Country	Location
15777	JM 2312	*D. ferruginea*	Tamil Nadu	India	5 km to Kundah; Ooty
15778	JM 2317	*D. ferruginea*	Tamil Nadu	India	9 km to Kotagiri; Ooty
15779	JM 2336	*D. ferruginea*	Tamil Nadu	India	20 km to Munar
15780	PR 4025	*D. ferruginea*	Maharashtra	India	
15781	PR 5429-1	*D. ferruginea*		Tanzania	Msata; Bagabogo
15782	PR 5709	*D. ferruginea*	Tamil Nadu	India	Dimbum, Nilgiri
15783	PR 5737	*D. ferruginea*	Tamil Nadu	India	Top Sangapatty; Thiruchirapalli
15784	JM 3499	*D. heynei*	Kerala	India	Kumuli, Udipi
15785	NKR 75	*D. heynei*	Karnataka	India	6 km to kumbarwad
15786	PR 4844	*D. heynei*	Kerala	India	Vandiperiyar - Kumuli 10 km; Idukki
15787	PR 4853	*D. heynei*	Kerala	India	Kumuli Pirmed 10km; Idukki
15788	PR 4863	*D. heynei*	Tamil Nadu	India	Yercaud, Salem

The World Chickpea and Pigeonpea Economy: Facts, Trends, and Outlook

ICRISAT plans to publish the latest facts and trends in the world pigeonpea and chickpea economy.

Objectives

1. To review major production and utilization trends of ICRISAT mandate crops
2. To highlight major issues affecting the production and utilization of these crops
3. To summarize available data on national and regional production, trade and utilization

Results

Considerable progress has been made and draft write-up completed. However, sections related to production and utilization in eastern Africa in particular and Africa in general are being redrafted by experts in the region familiar with these crops.

Preliminary results indicate that for both chickpea and pigeonpea there has been some diversification in the production during the last 15 years. The share of West Asia in chickpea production has increased from 8 to 13% and for pigeonpea the share of East Asia has gone up from 1 to 6%. However, South Asia still accounts for bulk of production for both these pulses. During the last 20 years, world chickpea production grew on an average by 2% per annum, mainly due to increase in area planted of 1.6 million ha during the period 1980-98. Australia's production of chickpea has grown from almost zero to 245 0001 per annum since the early 1980s. This growth was stimulated by the increasing demand from South Asia.

Pigeonpea production grew on an average by 1% per annum. Large area expansion under the crop in the eighties, mainly in south Asia, was an important contributing factor. Average pigeonpea yields have remained virtually stagnant during the last 20 years.

Low production growth of chickpea and pigeonpea has resulted in declining per capita availability of these pulses in the major producing regions. One consequence of this has been an increase in real prices for chickpea and pigeonpea relative to prices of cereals, milk, etc. This in turn has induced consumers to shift to cheaper sources of protein (milk, meat, etc.). Despite the shift, deficits in production, particularly in south Asia, are being met through imports.

Among the pulses, dry beans and dry peas constitute about 70% of total pulse trade, while chickpea and pigeonpea account for less than 10%. For chickpeas, Australia is the major exporter of *Desi* type, while Turkey dominates the *Kabuli* trade. Trade in pigeonpeas is relatively small, with no single country dominating exports, although in recent years Myanmar has emerged as an important exporter.

There has been considerable progress in developing improved varieties of chickpea and pigeonpea, but yield increases have not been able to match breakthroughs in productivity of competing crops like wheat, oilseeds etc. Increasingly these crops are being pushed to marginal areas further reducing their competitiveness. Pests and diseases are major factors affecting yield.

Pulses are still an important source of protein particularly for the vegetarian population. Increase in chickpea and pigeonpea yields will not only increase production but would reduce per unit cost which will translate into lower prices leading to increased consumption, especially among low and middle income consumers.

Chickpea

Breeding/Genetics

Association of Seed Mass Groups and Seed Yield in Kabuli Chickpea

1 S Mehla[1], R S Waldia[2], V P Singh[3], V S Lather[3], and S S Dahiya[2] (1. Regional Research Station, Uchani, Haryana, India; 2. Krishi Vigyan Kendra, Sonipat 131 001, Haryana, India; 3. Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Hisar 125 004, Haryana, India)

A hundred-seed mass in an important component of seed yield in view of its significance in breeding and ease of selection. A breeder can exercise selection successfully on the basis of seed mass and it is a well known fact that seed mass is a stable and highly heritable character as compared to other quantitative characters. Therefore, selection is likely to be effective. Seed mass has also been observed as an important factor in germination, seedling vigour, seedling mass, subsequent plant growth, and cooking quality attributes (Waldia et al. 1991, Waldia et al. 1996).

F_2 populations of the F_5 crosses of Kabuli gram were grown during 1994-95 postrainy season (25 Nov 1994) and more than one thousand seeds from each cross were grown to raise the F_2 population where each cross involved parents with different seed masses. Normal agronomical recommendations were followed for raising the crop and variation for seed mass and seed yield was studied and observations on 200 randomly selected plants from each of the five F_2 populations, i.e., C_1 = Gora Hisari x HK 88-232, C_2 = ICCV 2 x ICCC 32, C_3 = HK 89-96 x FLIP 91-14 C, C_4 = Gora Hisari x FLIP 91-14 C, and C_5 = ICCV 2 x FLIP 85-90 C were recorded.

These plants were separated into four groups on the basis of seed mass groups and seed yield where groups consisted 20.01 g (G_4). Correlation coefficients of seed mass with seed yield were worked out for each cross, up to four groups of seed mass separately. Some groups of seed mass in crosses were excluded for working out correlation coefficients due to limited number of plants.

Significant and positive association of 100-seed mass gave a variable picture in the sense that only a few different seed mass groups turned out to depict a significant positive association with the seed yield in different crosses. In a few crosses the range of seed mass groups was observed to fall beyond the limits of parents. This type of expression of characters often come due to transgressive segregation (also reported by Waldia et al. 1988). Generally, medium seed mass groups and often the small seeded

Table 1. Correlation coefficients of seed mass with seed yield in different groups of seed mass in Five F_2 crosses of Kabuli chickpea.

Parent	100-seed mass (g)	Cross	Four groups of seed mass (g)				Pooled correlation coefficients
			G1[1]	G2[2]	G3[3]	G4[4]	
Gora Hisari	21.89± 1.21	C1 = Gora Hisari x HK 88-232	–	0.389**	0.120	0.010	0.048
HK88-232	28.91 ± 0.46						
ICCV 2	20.53 ±0.35	C2 = ICCV2 x ICCC 32	0.964**	0.003	–	–	0.210**
ICCC 32	16.33 ±0.34						
HK 89-96	27.51 ±0.53	C3 = HK89-96 x FLIP 91-14C	0.268	0.354*	0.154	-0.243*	0.193*
FLIP91-14C	35.47 ±0.47	C4 = Gora Hisari x FLIP91-14C	0.1777	0.419**	-0.619**	-	0.344*
FLIP85-90C	32.50 ± 0.65	C5 - ICCV 2 x FLIP85-90C	-0.056	0.291*	-0.373**	-0.097	0.445**

1. <20.00 g; 2.0.01-25.00 g; 3.25.01-30.00; 4. >30.01 g.
* and ** significant at 1 and 5 percent of significance.

group showed association with seed yield and the 100-seed mass group showed association with seed yield. The 100-seed mass group ranging from 20.01 g to 25.00 g in the cross Gora Hisari x HK 88-232, HK 89-96 x FLIP 91-14C, Gora Hisari x FLIP 91-14C, and ICCV2 x FLIP 85-90C was found to be optimum in terms of best expression of seed yield. The seed mass group of less than 20.00 g in the cross ICCV 2 x ICCC 32 was optimum in terms of seed yield. This may be due to the fact that both the parents of this cross were comparatively small seeded. Thus, it is amply clear from the present study that the average expression of seed mass plays a key role in determining high seed yield, where the association between seed mass and seed yield is high and positive. High seed mass affects adversely and reduces the seed yield. It is also clear from this study as to why the large seeded kabuli types which are favored by the consumers, are mostly poor yielding. Therefore, from this limited data, it is suggested that while selecting kabuli genotypes for higher seed mass, yield level may also be kept in view to avoid reduction.

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Screening of Chickpea Germplasm Against Nematode

S S Ali and R Ahmad (Indian Institute of Pulses Research (IIPR), Kanpur 208 024, Uttar Pradesh, India)

Among the various nematode species attacking chickpea, the root knot nematode, *Meloidogyne javanica* (Treub) Chitwood, the lesion nematode. *Pratylenchus thornei* Sher and Allen, and the reniform nematode, *Rotylenchulus reniformis* Linford and Olivicra are most important in terms of yield losses. They can also aggravate fusarium wilt caused by *Fusarium oxysporum,* and back root-rot caused by *F. solani* (Ali 1995).

Managing these nematodes through the use of nematicides in chickpea is prohibitive due to the high cost of available nematicides. Hence the exploitation of resistance in germplasm and land races is a good alternative to manage the nematode problem under field conditions. For this reason, the present study was carried out.

Seed of 600 chickpea lines received from ICRISAT, Indian Institute of Pulses Research (IIPR) germplasm bank, and institute of chickpea breeding lines was sown in single line 2-m long in a field heavily infested with the above mentioned three nematode species. The initial inoculation was 1,2,5 juveniles g^{-1} of soil, of *M. javanica, P. thornei,* and *R. reniformis,* respectively. Two month old chickpea plants were uprooted carefully and the roots were washed and stained with acid fuchsin and lactophenol and visually observed. Observations were made on galls on the scale of 1-5 (where 1 = no galls/no egg mass, and 5 = above 100 galls/egg mass) for root knot nematode and the lesions were counted on a 1-10 scale (where 1 = no lesion, and 10 = root portion full of heavy lesion) for lesion nematode. For reniform nematode, infestation was recorded by counting the exposed females on the root system on 1-10 scale (where 1 = exposed female and 10 = above 100 exposed females).

Out of 600 chickpea lines tested, majority of them were found infested with root knot nematode and the galling index was in the range of 4-6 and were graded as highly susceptible to *M. javanica.* None was found immune while 7 entries were found to bear minimum population and infestation ranging from 2 to 2.8. Multiple lesions along with browning symptoms were commonly observed on roots showing moderate to heavy infestation of *P. thornei* and most of the entries were highly susceptible and ranged between 7 and 10. Only 17 lines were found resistant to *P. thornei* and infestation ranged from 3 to 5. For *R. reniformis* all the test lines were found heavily infested except IPC 96-69 and ICC 6928 where a few females were found attached to the root system. From an analysis of all of the entries against three nematode species, entries ICC 16614 and IPC 96-69 had shown dual resistance against *M. javanica* and *P. thornei* while, ICC 6928 and IPC 96-69 had shown resistance to *P. thornei* and *R. reniforms.* Only one entry, i.e., IPC 96-69 was found promising against all the three nematode species studied (Table 1). These lines need further screening before they can be used in the breeding program as resistant parents to these nematodes.

Table 1. Chickpea germplasm exhibited different degrees of resistant to three nematode species (number of entries screened = 600).

M. javanica (MJ)	*P. thorenei* (PT)	*R. reniformis* (RR)	MJ + PT	PT + RR	MJ + PT + RR
ICC 16614	ICC 16614	IPC 96-69	ICC 16614	ICC 6928	IPC 96-68
ICC 6444	ICC 6428	ICC 6928	IPC 96-69	IPC 96-69	
IPC 94-105	ICC 5824				
IPC 96-49	ICC 6825				
IPC 86-98	ICC 6910				
IPC 96-69	ICC 6918				
IPC 96-70	ICC 6928				
	ICC 6938				
	ICC 6956				
	ICC 6950				
	ICC 6953				
	ICC 6962				
	ICC 7962				
	ICC 6983				
	ICC 6990				
	PDE 2				
	IPC 96-67				
7	17	2	2	2	1

Acknowledgment. Authors thank Dr S B Sharma (formerly ICRISAT) for providing chickpea germplasm and also the Director, IIPR, Kanpur for providing facilities to conduct these studies.

Reference

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L 551 - A New Kabuli Chickpea Cultivar for Punjab State, India

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Kabuli chickpea *(Cicer arietinum* L.) gives better financial returns than the *desi* type. Efforts were made in the past to develop a medium bold seeded kabuli gram cultivar L 551 at Punjab Agricultural University, Ludhiana, Punjab, India. Over a period of time the old cultivar of kabuli gram L 550 had become susceptible to Ascochyta blight, fusarium wilt, root rot, and foot rot diseases whereas the new cultivar, L 551, possesses high yield potential and resistance to wilt. It is moderately resistant to Ascochyta blight, which is the most destructive disease of the region. This cultivar was developed from the cross ICCC 32 x ICCX 780581-BH-10H-BH, and was attempted at ICRISAT, Patancheru and its F_2 seeds were supplied to PAU, Ludhiana. Pedigree method was used to evolve this cultivar, which was released in 1999 for cultivation throughout the Punjab state except humid areas.

The yield performance of L 551 from 1989 to 1996 in various varietal trials conducted in the state is given in Table 1. The 51 trials comprise of research varietal trials, agronomic trials, adaptive trials, and frontline demonstrations conducted at different locations in the state. The new cultivar gave an average yield of 1901 kg ha^{-1} against 1625 kg ha^{-1} of control cultivar L 550 and showed 16.9% superiority over the control cultivar. L 551 was also tested in the IVT (*kabuli*) of All India Coordinated Trials during the postrainy season of 1997-98. On the basis of zonal mean, it had occupied the first position in North West Plain Zone (NWPZ) and the second position in Central Zone (CZ). The new cultivar also performed well on farmer's fields. Demonstrations were conducted at

Table 1. Performance of chickpea cultivars L 551 and L 550 in various trials from 1989 to 1996.

Trials	Year(s)	Number of trials	Yield (kg ha^{-1}) L 551	Yield (kg ha^{-1}) L 550	% increase over L 550
Varietal Trials (Research)	1989-90 to 1994-95	15	2363 ± 154	1895 ± 134	24.7
Agronomic Trials (Research)	1993-94 to 1994-95	2	1745 ± 289	1630 ± 269	7.0
Adaptive Trials (Farm Agril. Services, PAU)	1994-95	13	1646 ± 138	1354 ± 89	21.6
Adaptive Trials (Department of Agriculture, Punjab)	1994-95	17	1671 ± 95	1576 ± 70	7.0
Frontline Demonstration	1995-96	4	2056 ± 189	1702 ± 110	20.7
Overall mean		47	1901	1625	16.9

Table 2. Reaction of chickpea cultivars L 551 and L 550 to different diseases at Ludhiana under artificially augmented conditions from 1989 to 1995.

Year	Blight (grade) L 551	Blight (grade) L 550	Wilt (%) L 551	Wilt (%) L 550	Foot-rot (%) L 551	Foot-rot (%) L 550	Root-rot (%) L 551	Root-rot (%) L 550
1989-90	7.0	9.0	8.9	5.0	19.1	5.0	16.2	0.0
1990-91	7.0	9.0	10.1	NT	9.9	NT	10.1	NT
1991-92	8.0	9.0	12.5	21.6	5.4	19.0	5.4	6.69
1992-93	6.0	9.0	9.5	56.1	4.7	21.2	0.0	13.6
1993-94	6.0	9.0	7.1	63.1	7.1	12.1	3.5	8.8
1994-95	5.0	9.0	11.5	50.7	5.6	17.2	5.6	14.9
Mean	6.3	9.0	10.1	41.2	8.2	15.3	6.6	9.8
(Common trials)	(7)	(7)	(7)	(6)	(7)	(6)	(7)	(6)

NT = Not tested.

Table 3. Culinary and nutritional quality of kabuli chickpea cultivars L 551 and L 550[1].

Variety	100-seed mass (g)	Density 12 h (%)	Water absorption 12 h soaking (%)	Volume expansion	Protein (%)	Cooking time (min)
L 551	20.2	1.27	108.4	140.7	23.18	70
L 550	21.5	1.29	104.5	146.2	23.12	75

1. Mean over 3 years.

four locations during the postrainy season of 1995-96. L 551 gave a yield of 2056 kg ha^{-1} against 1702 kg ha^{-1} of L 550 (Table 1).

The disease reaction of L 551 and control cultivar L 550 to Ascochyta blight, wilt, foot rot, and root rot from 1989 is given in Table 2. The average Ascochyta blight score of L 551 was 6.3 against 9.0 for L 550. In 6 years, the incidences of fusarium wilt, foot rot, and root rot were 10.1, 8.2, and 6.6% in L 551 as compared to 41.2, 15.3, and 9.8% in control cultivar L 550, respectively. This means the new cultivar has better resistance to these diseases than the control cultivar. Its culinary and nutritional quality is also good (Table 3). Therefore, the new cultivar offers a better opportunity to the fanners of Punjab.

Preliminary Screening of Chickpea Genotypes for Resistance to Narrow Leaf Disease (Bean Yellow Mosaic Virus) in the Punjab

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In some chickpea varietal trails conducted at the Punjab Agricultural University, Regional Research Station, Faridkot, during the postrainy season 1998-99, leaflets of top leaves of many genotypes became narrow. The leaves below the affected branches showed yellowing or interveinal chlorosis or mosaic depending on the genotype, and the overall heights of the affected plants were reduced. Such plants produced a very few distorted flowers that developed into very small pods, and seeds from infected plants were black, small, and shriveled. These were the symptoms of narrow leaf disease (Fig. 1) and this is the first record of this disease on chickpea from Punjab. Similar symptoms of narrow leaf disease on chickpea have been reported by Chalam (1982) from Andhra Pradesh.

Dafallah and Hussein (1994) reported that bean yellow mosaic potyvirus (BYMV) was the most common mechanically transmitted virus detected on chickpea in Sudan. Mouhanna et al. (1994) conducted serological (ELISA) tests and concluded that BYMV commonly occurred on chickpea in Syria. Later, Makkouk et al. (1995) also observed natural occurrence of bean yellow mosaic potyvirus on chickpea and faba bean in Sudan. Recently, Quizbouben and Fortass (1997), on the basis of serological tests using polyclonal antisera and monoclonal antibody, found that BYMV was present on chickpea in Morocco. The incidence of this disease per field was 83%. This is the first report of BYMV occurrence on chickpea in

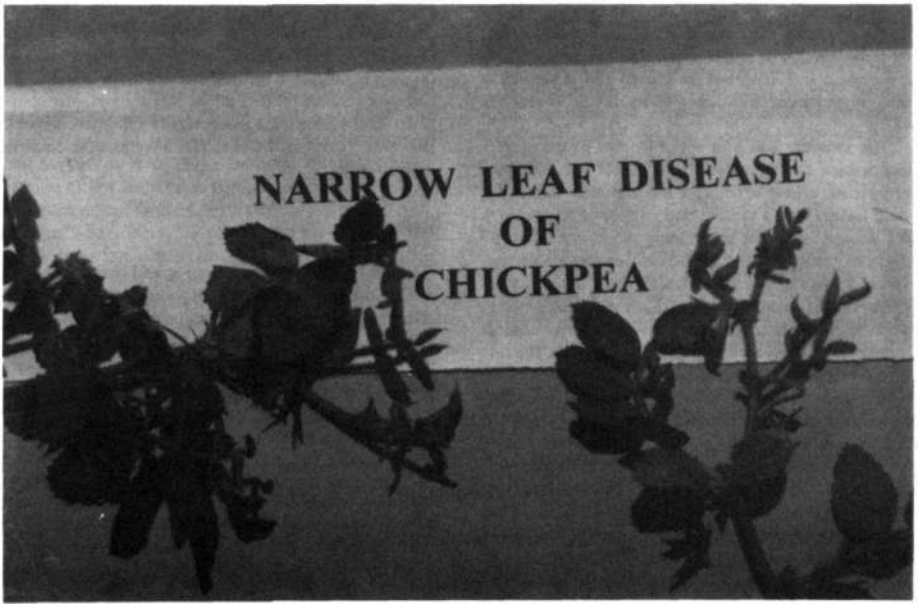

Figure 1. Narrow leaf disease of chickpea.

Table 1. Chickpea genotypes having no symptoms of narrow leaf disease (BYMV) during postrainy season, 1998-99, Faridkot, Punjab, India.

Desi type

BCP Nos. 17, -73, BG Nos. 117, -267, -1003, -1077, PG 92-18, BGD Nos. 111, -112, BGM Nos. 525, -529, BSD 109, C 235, CSG 8962, CSJD Nos. 869, -901, FG Nos. 559, -703, -711, -728, -729, -785, -897, -929, -930, -932, -934, -937, -938, -971, 984, -1006, -1007, -1008, -1013, -1014, -1015, -1016, -1017, -1018, -1019, -1020, -1021, -1022, -1025, -1028, -1029, -1030, -1031, -1031, -1032, -1033, -1034, -1035, -1036, -1037, -1038, -1039, -1040, -1041, -1043, -1044, -1045, -1046, -1047, -1049, -1050, -1051, -1052, -1053, -1054, -1055, -1056, -1062, -1063, -1064, -1066, FGM Nos. 1, -2, -4, -7, -22, -24, -25, -48, GL Nos. 94022, -96010, -96086, -96123, -97023, -97043, GCP 9516, GNG Nos. 663, -1251, -1257, H Nos. 93-106, -95-19, -95-23, -95-122, -95-123, HC 1, ICP1C 5, IPC 97-1, PBG 157, Phule G Nos. 93009, -95007, -97-6, RSG Nos. 895, -906, -945, -959, WCG Nos. 1-1,-2

Kabuli type

BG Nos. 1073, -1082, BGD Nos. 117, -118, FGK Nos. 869, -948, -949, -987, -989, -990, -1000, -1067, -1068, -1069, -1070, -1071, -1072, -1074, -1075, -1076, -1076, -1077, -1079, -1080, -1081, -1083, -1084, -1085, -1086, -1088, GLK Nos. 95056, -95058, -95060, -95061, -95062, -95069, -95071, -95072, -95075, -95078, -95081, -95082, -95085, -95087, -95089, -95091, -96203, -96204, -96206, GCP 107, GNG Nos. 1282, -1288, -1292, L 551, Phule G Nos. 95412, -95418, RSGK 641

Morocco. Similarly, Yahia et al. (1997) reported that BYMV caused narrow leaf disease on chickpea in Algeria for the first time. They also observed that it is transmitted by three species of aphid (*Acyrthosphon pisum, Aphis craccivora,* and *Aulacorthum solani)* and is carried in seed cotyledons of chickpea cultivars, ILC 3279 and 1LC 482.

The intensity and host species range of the narrow leaf disease, caused by BYMV, suggests that it can be a very serious disease of chickpea and may cause substantial yield losses. With a view to find sources of resistance to the disease, we made preliminary observations in 267 chickpea genotypes from 5 All India Coordinated Varietal Trials, 7 State Trials, and 5 Local Trials during 1998-99 postrainy season at Faridkot. Each trial was grown in randomized complete block design with 3 or 4 replications. Number of rows in each plot varied from 4 to 8. The row length was 4 m with a spacing of 30 cm.

The genotypes were rated as susceptible (showing disease symptoms) or resistant (no disease symptoms). The records were taken in the month of March under natural epiphytotic conditions. Out of 267 genotypes, 170 genotypes were found resistant (Table 1) and the remaining 97 susceptible. Five genotypes, FG 921, PBG 164, Phule G 5, RSG 882 (*desi* type) and GLK 95070 (*kabuli* type), were highly susceptible to the disease. About 70% of the plants in these genotypes showed disease symptoms. Of the 97 susceptible genotypes, 80 (82.47%) were of *desi* types and 17 (17.53%) *of kabuli* types.

Eleven resistant genotypes, FG 559, FG 703, FG 711, FG 897, GL 94022 (*desi* type), and FGK 869, FGK 948, GLK 95071, GLK 95091, GNG 1282, GNG 1292 (*kabuli* type) yielded more than the control cultivars and the other genotypes in different varietal trials. The resistant genotypes can be used as donor parent to transfer resistance into, otherwise, agronomically superior cultivars. However, these genotypes should be retested to confirm their resistance.

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Effect of Soil Solarization on Populations of Chickpea Nematodes

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Root-knot *(Meloidogyne artiellia* Franklin), lesion *(Pratylenchus thornei* Sher *et* Allen) and cyst nematode *(Hetreodera ciceri* Vovlas, Greco *et* Di Vito) are important nematodes of chickpea *(Cicer arietinum* L.) in the West Asia and North African (WANA) region (Di Vito et al. 1994). If not controlled, they can cause severe root damage and crop losses. Resistance in chickpea cultivars has been found for root-knot and lesion nematodes but not for the cyst nematode (Greco and Di Vito 1993). Soil solarization has been shown to be effective in nematode control (Di Vito et al. 1991). However, its use is limited because of low benefits and problems of large scale use by resource poor farmers. Strip cropping of cereals with legumes within the same field in the same season is a common feature of the farming systems of WANA. In such systems, solarization can be effective as a means of nematode control in targeted plots within the strips.

Experiments were carried out at the ICARDA research farm in Tel Hadya, Syria, during the 1996/97 cropping season to study the efficacy of soil solarization on chickpea nematode populations for possible use in nematode control. Included in the 3 solarization treatments was a nematicide application, Vydate L® (active ingredient: Oxamyl). The field plot used for the experiments had a known history of severe nematode infestation on legumes. Root-knot, lesion, and cyst nematodes were known to be prevalent in this field.

Soil samples were collected to determine the population of these nematodes in the plots before and after applying the solarization treatments. The treatments consisted of mulching 6 x 11 m plots with: 1) a single layer of transparent polyethylene film 50 µm thick, 2) a double layer of the transparent film, 3) a single layer of black polyethylene film 50 urn thick, and 4) a spray treatment with the nematicide, Vydate. The control plots were left without any treatment. All treatments were replicated 3 times in a completely randomized block design. To improve heat conductivity, the plots were irrigated (5-10 mm h^{-1}, for 3 5 hrs d^{-1} for 5 days) just before covering, and the covers were kept in place for 8 weeks from mid-July till mid-August. Soil temperatures before covering ranged from 18°C to 25°C, and went up to 35-50°C during covering at a depth of 5-10 cm.

Five soil samples were taken at random from each plot for nematode population counts before and after solarization. Root lesion and root-knot nematodes from 200 cm^1 soil sub-samples were extracted by Coolen's method (1979). Cysts of *H. ciceri* were extracted from 200 g air-dried sub-samples using a Fenwick can. The cysts were counted and egg numbers determined. Eight weeks after removing the plastic mulch, the chickpea cultivar F 82-150 C (Ghab 3) was planted on 4 row plots spaced at 45 cm apart in each plot. Four weeks after planting, the nematicide was spray-inoculated at 3 L ha^{-1}. Soil samples were collected from the nematicide-treated plots 4 weeks after the chemical application. Plots were observed for visual differences based on foliar yellowing symptoms and stunting. Destructive sampling was done using 10 plants per plot, from which severity ratings (1-9), were given for root-knot and lesion nematode infections based on the root symptoms observed. Plots were harvested at maturity.

The nematode population in the plots before and after the treatments is shown in Table 1. The most effective treatment was the use of double transparent polyethylene mulch. This treatment eliminated the populations of the lesion and cyst nematodes and drastically reduced the population of the root-knot by 94%. Solarization with the single layer transparent plastic was also effective in nematode control. It also completely eliminated the population of cyst nematode, drastically reduced the populations of the root-knot, and lesion nematodes. The black polyethylene covering was not as effective as the transparent one in nematode control. It had no effect on lesion nematode population, but reduced the population of the root-knot nematode by 50% and that of the cyst nematode by 85%. The nematicide application had virtually no effect on any of the nematode populations.

Seed yield increased by more than 73% with the double transparent covering, and by about 54% with single covering. There were no significant yield differences between the black covering and the nematicide treatments

Table 1. Effect of soil solarization on chickpea nematode populations.

Treatment	Counts	*Meloidogyne artiellia*	*Pratylenchus thornei*	*Heterodera ciceri*	Total	Change (%)
Two layer, transparent	Before sol	926	819	795	2540	98
	After sol	52[1]	0[1]	0[1]	52	
One layer, transparent	Before	634	519	660	1813	87.4
	After	126[1]	102[1]	0[1]	228	
One layer, black	Before	869	701	930	2500	46.4
	After	460[1]	739	141[1]	1340	
Nematicide	Before	680	530	1050	2260	5.3
	After	629	496	1015	2140	
Control	Before	906	728	1125	2759	-0.14
	After	960	763	1040	2763	

1. Nematode population counts after treatments were significantly different ($P = 0.05$) from counts before treatments.

(Table 2). From the yield increases and the reduction in the nematode populations, there is scope to use strip solarization for targeted treatment of fields with nematode problems, especially to control nematodes such as the cyst nematode for which there is presently no resistance in chickpea cultivars. Soil solarization may not be suitable for chickpea production in many countries because of low benefits. It has however been shown to be effective against several soilbome pathogens (Katan 1987) and thus could have added effects on soilborne fungi where these are interacting with nematodes to cause poor plant growth and reduced yields.

Table 2. Effect of soil solarization on chickpea seed yield.

Treatment	Mean grain yield (kg ha^{-1})	% yield increase
Two layer, transparent	1371	73.5
One layer, transparent	1217	53.9
One layer, black	1052	33.1
Nematicide spray	952	20.2
Uncovered control	767	-
LSD (0.05)	121	-

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Occurrence of *Sclerotinia* Stem Rot of Chickpea in Madhya Pradesh, India

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Chickpea is cultivated as a rainfed postrainy season crop in Madhya Pradesh. *Sclerotinia* stem rot is an important disease in the north Indian states of Uttar Pradesh, Punjab, Himachal Pradesh, Jammu and Kashmir, Haryana, and parts of Rajasthan due to intermittant and heavy rains during the crop season. The disease causes 10-100% yield loss (Singh and Gill 1979, Singh et al. 1989). However, there is no record of its occurrence in Madhya Pradesh. In the 1998-99 growing season, sporadic incidence of this disease was recorded in varietal trails of the All India Coordinated Research Project of Chickpea at Jabalpur, Madhya Pradesh, India. The disease ranged from 1 to 7 on a 1-9 rating scale in different varieties. Of the 91 genotypes assessed under natural conditions of disease incidence, 21 were found free from infection (rating 1), 2 scored a rating of 2, i.e., in traces. These genotypes need further evaluation in hot spot areas.

The symptoms of the disease appeared as chlorotic or drying of branches on whole plants scattered across the field. The affected plants rotted at the collar region or at any point on the branch. Later, affected plants/branches turned yellow or drooped while retaining their green color, followed by drying and turning straw colored. A web of white mycelial strands appeared at the collar region and above covering the base of the branches. Whitish, brownish irregular shaped sclerotia were seen mingled with mycelial strands on branches and also inside the stem.

Isolations were made from the infected leaflets and stem and the pathogen was identified as *Sclerotinia sclerotiorum* (Lib.) de Bary. The pathogenecity of the fungus was tested on plants grown in a pot house. The plants were inoculated with mycelial mat and the pathogen was re-isolated from artificially infected plants. The specimens and the culture were preserved for further work.

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Management of Root-knot Nematodes-wilt Complex in Chickpea

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Chickpea (*Cicer arietinum* L.) suffers from various plant parasitic nematodes. Root-knot nematodes, *Meloidogyne incognita* and *M. javanica,* are key pests in the Indian subcontinent (Sharma and McDonald 1990). Chickpea wilt caused by *Fusarium oxysporum* f. sp. *ciceri* appears early and disease severity increases in the presence of root-knot nematodes (Rao and Krishnappa 1994a). Hence, an experiment was carried out to manage root-knot nematodes-wilt complex on chickpea in the field during 1995-96 and 1996-97.

Seed treatment of carbendazim @ 0.1% (w/w) + carbosulfan @ 0.75% (w/w) along with soil application of carbendazim granules @ 0.5 kg ha^{1} in single dose as basal application + carbofuran granules @ 2.0 kg ha^{-1} in two equal splits; one at the time of seeding and another at 30 days after seeding was tried on two chickpea varieties; Avrodhi (wilt resistant) and Dahod Yellow (wilt susceptible). Both the varieties without any treatment served as control. The experiment was conducted in a root-knot nematodes (mix population of *Meloidogyne incognita* and *M. javanica)* and wilt fungus *(Fusarium oxysporum* f. sp. *ciceri)* sick field. The crop was sown at 30 cm x 10 cm spacing in gross plot of 1.8 m x 2.5 m (net plot of 1.2 x 2.5 m) in randomized block design with five replications. Other recommended practices for the crop were followed. Observations on initial plant stand were recorded after emergence while other observations were recorded at maturity of crop. Soil samples were collected from each plot after harvest of the crop and nematode population was estimated from 100 g sample of each plot. Root-knot disease intensity was recorded using 0-5 rating scale (0 = free, 5 = maximum disease intensity).

The data pooled over a period of two years (Table 1) indicated that both the chickpea varieties tested were statistically at par with each other with respect to initial plant stand and plant height. Moreover, they were statistically equally susceptible to root-knot disease. However the Avrodhi variety had less intensity of wilt disease as compared to Dahod Yellow. Grain yield production was significantly more by Dahod Yellow but its fodder yield production was significantly less than Avrodhi.

Table 1. Management of root-knot nematodes-wilt complex through host resistance and application of pesticides.

Treatment	Initial plant stand	Plant height (cm)	Grain yield (kg ha^{-1})	Fodder yield (kg ha^{-1})	Plants wilted (%)	Root-knot index (0-5)[1]	Final nema popn. 100 g^{-1} soil
Variety							
Dahod Yellow	97[a]	57.2[a]	2008[a]	4142[b]	52.2[a]	2.16[a]	94[a]
Avrodhi	97[a]	55.2[b]	1049[b]	5028[a]	10.4[b]	2.18'	93[a]
SEm	1.2	0.9	37	78	1.6	0.05	4
Pesticides							
Treated	98'	60.6[a]	2167[a] (+143.48)	5820[a] (+73.73)	17.7[b] (-60.58)	1.78[b] (-30.47)	54[b] (-59.40)
Control	95[b]	51.8[b]	890[b]	3350[b]	44.9[a]	2.56'	133-
SEm	0.5	0.9	169	78	4.0	0.05	4
Significant interactions	YxV	Y, VxT	Y, YxT, YxVxT	VxT	Y, YxT, VxT	Y	–
CV (%)	2.2	7.0	10.7	7.7	23.0	10.6	20.1

1. 0 = Free; 5 = Maximum disease intensity.

Figures indicating common letters do not differ significantly from each other at 5% level of significance according to DNMRT.

Treated = Seed treatment with carbendazim @ 0.1% (w/w) (Subeej 25% ST) + carbosulfan @ 0.75% (w/w) (Marshal 25 ST) + soil application of carbendazim granules @ 0.5 kg ha^{-1} (JKStein 5G) in single dose as basal application + carbofuran granules @ 2.0 kg ha^{-1} (Furadan 3G) in two equal splits; one at the time of seeding and another at 30 days after seeding.

There was also significant effect of seed treatment and soil application of fungicides and nematicides on all the attributes under study. Pesticidal treatment showed significant improvement in seed germination as judged by plant stand and plant height. It also significantly increased grain and fodder yield. The increase was 143.48% in grain yield and 73.73% in fodder yield whereas the incidence of wilt disease was reduced by 60.58%. The treatments were found very effective in controlling root-knot disease and there was 30.47% reduction in root-knot index and 59.40% reduction in final soil nematode population.

The results indicated that chickpea variety, Avrodhi, is resistant to wilt disease, but susceptible to root-knot nematodes. Its grain yield production is low so it is not suitable for cultivation in Gujarat, India. Though Dahod Yellow is susceptible to both diseases, it gives higher yield as compared to Avrodhi. Root-knot nematodes, *Meloidogyne incognita* and *M. javanica* as well as wilt disease of chickpea caused by *Fusarium oxysporum* f. sp. *ciceri* can be effectively managed by seed treatment of carbendazim @ 0.1% (w/w) + carbosulfan @ 0.75% (w/w) coupled with soil application of carbendazim granules @ 0.5 kg ha^{-1} and carbofuran granules @ 2.0 kg ha^{1}.

The results are in agreement with the findings of Mani and Sethi (1984) and Rao and Krishnappa (1994b) who observed increase in chickpea through seed treatment with nematicide and fungicide. Seed treatment with carbofuran and carbendazim has also proved effective for management of root-knot nematodes-wilt complex (Anonymous 1989).

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Effect of Interaction Between *Meloidogyne javanica* Pathotype 1 and Wilt Inducing Fungus, *Fusarium oxysporum* f. sp. *ciceri* on Chickpea

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Chickpea (*Cicer arietinum* L.) suffers from nematode diseases and among the various plant parasitic nematodes, root-knot nematodes, *Meloidogyne incognita* and *M. javanica,* are key pests in the Indian subcontinent (Sharma and McDonald 1990). In India, Upadhyay and Dwivedi (1987) reported 40% yield loss in chickpea due to *M. incognita.* Chickpea wilt caused by *Fusarium oxysporum* f. sp. *ciceri* is widely distributed and reported from almost all the chickpea growing regions in the world (Haware et al. 1990). The present study was conducted to find out the interaction between *M. javanica* pathotype 1 and *F. oxysporum* f. sp. *ciceri.*

M. javanica pathotype 1 (Mj pt.1) and *F. oxysporum* f. sp. *ciceri* were tested on chickpea cultivar Dahod Yellow during 1995-96 and 1996-97 where earthen pots of 15 cm diameter were disinfected with 4% formaldehyde and filled with steam sterilized soil (1 kg pot^{-1}). Three seeds of Dahod Yellow were sown in the center of each pot after surface sterilization with 0.1% mercuric chloride for 2 minutes. On germination, plants were thinned to one per pot. Mj pt. 1 second stage larvae, extracted as per Petridish Assembly Method (Chawla and Prasad 1974), were inoculated in the rhizosphere of each plant @ 1000 larvae/plant per treatment. Spores of *F. oxysporum* f. sp. *ciceri* (Foc) collected from Potato Dexrose Broth (PDB), were suspended in sterile distilled water (with 0.1% Tween 20). Foc spores were added @ 2 x 10^9 spores/ plant per treatment in the rhizosphere of plants.

The treatments were: a) Mj pt. 1 alone, b) Foc alone, c) Mj pt. 1 + Foc (simultaneous), d) Mj pt. 1 followed by Foc 2 wks after (Mj pt. 1 + Foc-2 wks), e) Foc followed by Mj pt. 1 2 wks after (Foc + Mj pt. 1-2wks), and f) no nematode or fungus inoculation (control). The treatments were arranged in completely randomized design with five repetitions in a net house maintained at 22 ± 3°C. Watering and other necessary operations were taken as needed. Ninety days after inoculation, plants were removed carefully, washed free of soil, and used for recording observations.

Pooled data revealed that maximum plant height and fresh shoot and root mass were observed in control plants and minimum in simultaneous inoculation of fungus and nematode (Mj pt. 1 + Foc). Maximum root-knot index was observed in Mj pt.1 treatment while minimum in Foc + Mj pt.1-2 wks and Mj pt.1 + Foc treatments while

Table 1. Interaction between *Meloidogyne javanica* pt.1 and *Fusarium oxysporum* f. sp. *ciceri* in relation to growth and development of chickpea cultivar Dahod Yellow plants and nematode multiplication and wilt disease incidence.

Treatments	Plant height (cm)	Fresh mass (g)		RK1 (0-5)[1]	Final nematode population plant^{-1}		Reproduction rate		Wilting	
		Shoot	Root		Population (Log X+1)	% decrease over Mj pt.1	Rate	% decrease over Mj pt. 1	% wilting of plants	%inrease over Foc
Control	31.2^{a}	13.26^{a}	13.90^{a}	0.00^{c}	0.000^{c} (0)	-	-	-	0.0	-
Mj Pt. 1	24.0^{C}	8.71^{bc}	7.05^{d}	3.90^{a}	3.942^{a} (8885)	-	8.86	-	0.0	-
Foc	25.5^{b}	9.81^{b}	11.37^{b}	0.00^{c}	0.000^{e} (0)	-	-	-	40.0	-
Mj Pt.1 + Foc	15.8^{e}	7.42^{c}	6.30^{d}	3.30^{b}	3.673^{c} (4960)	44.18	4.96	44.02	70.0	75.0
Mj Pt.1 + Foc-2 wks	17.9^{d}	7.71^{c}	7.33^{d}	3.70^{a}	3.816^{b} (6665)	24.99	6.67	24.72	70.0	75.0
Foc+Mj Pt.1-2 wks	22.9^{C}	9.02^{bc}	8.78^{c}	3.10^{b}	3.507^{d} (3245)	63.48	3.25	63.32	50.0	25.0
SEm	0.4	0.52	0.35	0.11	0.03	-	-	-	-	-
CV (%)	5.3	16.9	11.7	14.6	3.5	-	-	-	-	-

1. 0 = Free; 5 = Maximum disease intensity.

Mj pt.1 = *M. javanica* pt.I @ 1,000 J^2/plant, Foc =*Fusarium oxysporum* f. sp. *ciceri*@ 2.0 x 10^9 spores plant^{-1}.

Figures indicating common letters do not differ significantly from each other at 5% level of significance according to DNMRT.

Figures in parentheses are retransformed values.

the other treatments had moderate effect. Final nematode population was highest in Mj pt. 1 treatment followed by Mj pt. 1 + Foc-2 wks, Mj pt. 1 + Foc, and Foe + Mj pt. 1-2 wks treatments. There was 44.18%, 24.99%, and 63.48% reduction in final nematode build up in Mj pt.1 + Foe, Mj pt.1 + Foc-2 wks, and Foc + Mj pt. 1–2 wks treatments, respectively over Mj pt.l treatment. Similarly, nematode reproduction rate was also reduced by 44.02%, 24.72%, and 63.32% in Mj pt.l + Foc, Mj pt.l + Foc-2 wks, and Foc + Mj pt.1-2 wks treatments, respectively over Mj pt. 1.

Foc alone could cause only 40% wilting of plants but the severity of wilt disease increased when *M. javanica* pathotype 1 was present along with the fungus. There was 75% increase in wilting when both the organisms were inoculated either simultaneously or fungus was inoculated two weeks after nematode inoculation whereas 25% increase in wilt disease was recorded when nematodes were inoculated two weeks after fungus inoculation. The increase in wilt severity may perhaps be due to root injury caused by nematodes which provided avenues for entry of wilt fungus. There was reduction in nematode multiplication and reproduction rate in presence of fungus.

The results obtained under the study are in confirmation with the findings of Nath and Dwivedi (1980) and Sharma and Cerauskas (1985).

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Effect of Organic Manures, Fertilizers, and Nematode on the Control of Root-knot Nematode and Yield in Chickpea

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Chickpea is one of the potential legumes in Tearai belt of Nepal but its productivity is very low even as the area under cultivation is rapidly decreasing. Diseases like Botrytis gray mold, Ascochyta leaf spot and wilts are considered to be one of the potential threats to chickpea production in Nepal. In addition, plant parasitic nematodes, mainly *Meloidogyne* spp is also found to be associated with reduction in yield in chickpea. Manandhar and Amatya (1988) observed 51.8% yield reduction in chickpea in Rampur, due to root-knot nematode (RKN) alone. Poultry manure is reported to reduce the root-knot population in the field (Castillo 1985). Thus this experiment was conducted to evaluate the effect of maure of different animal species, chemical fertilizers and carbofuran on the incidence of root-knot nematode and yield of chickpea in Rampur.

Materials and Methods

An experiment was conducted in naturally infested soil with root-knot nematode (*Meloidogyne* spp.) in completely randomized block design with 3 replications. The plot sizes were 9 m^2 each with the following treatments; poultry manure, goat manure, farmyard manure (FYM), chemical fertilizers, combination of FYM and chemical fertilizers, FYM, chimical fertilizers, carbofuran, and control. Chickpea variety Dhanus was planted as per the recommended package of practices in 1996 and 1998 on the Rampur Campus Farm. After 60 days, five plants per plot were uprooted, one from each corner and one at the center and brought to IAAS laboratory for observation of galls. In the laboratory galling index was

Table 1. Effect of organic manures, fertilizers, and carbofuran on gall index and chickpea yield at Rampur, Nepal (1996 and 1998).

Treatments	1996			1998		
	Yield (g plot^{-1})	Increase over control	Gall index[1]	Yield (g plot^{-1})	Increase over control	Gall index[1]
Poultry manure	666.6a	635	3	402a	373	4
Goat manure	101.6b	70	5	165b	136	5
Farmyard manure (FYM)	40.0b	8.4	7	66.8b	37	7
Chemical fertilizers (NPK)	43.6b	12	7	50.0b	21	6
Half FYM+Half NPK	200.6b	169	5	85.0b	56	5
Half FYM+Half NPK+Carbofuran	205.3b	173.4	5	132b	103	5
Control	31.6b	-	9	29c	-	7
LSD	238.7			284.8		

1. Gall index 1-9 scale.
In column, means with the same letter are not significantly difference with DMRT (P = 0.05 level).

done on the basis of Baker, 1985 and at maturity, grain yield was collected and recorded.

Results and Discussion

To study the effect, galls were indexed based on Baker, 1985 and yields were recorded in each treatment. Low gall index was observed in poultry manure applied plot in both the years and the highest in control (Table 1). The lower gall index may be due to reduced populations of *Meloidogyne* (Castillo 1985). Significantly highest chickpea yield was also observed in the plots supplied with poultry manure in both the years (Table 1). This may be due to reduced root-knot namatode population in the soil and also manure supplied nutrients to the chickpea thereby increasing the chickpea yield.

The yield increase over control was the highest in the plots supplied with poultry manure in both the years and the lowest with FYM in 1996 and chemical fertilizers in 1998. Carbofuran was not effective in reducing namatode population and no difference in gall index and chickpea yield was observed as compared to control. That may be due to lack of control by carbofuran on root-knot nematode population. In Tanahu, furadan was not effective to reduce the RKN in blackgram (Pradhanag et al. 1992).

Poultry manure which is easily available to the farmers in Chitwan as the poultry farming is popular in this region, seemed to be potential resource available to the farmers in place of chemical fertilizers, thereby increasing the chickpea production and reducing root-knot problem in the fields.

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Screening Chickpea Genotypes for Resistance to *Helicoverpa armigera*

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Insect-pests constitute an important biotic stress on plants and it is estimated that about 13% of the crop produce is damaged by insects the world over (Sethi 1994). Chickpea is the most important cool season food legume that is grown mainly on the marginal lands in south-western regions of Punjab. The primary reason for the farmers reluctance to cultivate chickpea is its susceptibility to gram pod borer (*Helicoverpa armigera* Hub.), a serious pest that occurs regularly and causes about 10% yield loss to the crop (Reed et al. 1987). The country witnessed unprecedented outbreak of the pest particularly in North India during 1996. Even though various chemical control measures have been devised to minimize the losses caused by pod borer, this pest has developed substantial resistance to insecticides. Both ecologically and economically, breeding chickpea cultivars having resistance to the pest is the most important component of integrated pest management. A major strength of the breeding program, to develop pod borer resistant cultivars, depends upon the well stocked germplasm collections and identification of resistant donors. The main objective of the present study was to screen diverse chickpea germplasm for pod borer resistance under unprotected field conditions.

Sixty-two chickpea germplasm accessions acquired from the International Crops Research Institute for the Semi-Arid Tropics (1CR1SAT), Patancheru, India, International Centre for Agricultural Research in the

Table 1. Mean performance of selected chickpea accessions for different characters.

Accession	Pods plant^{-1}	Damaged pods (%)	Yield plant^{-1} (g)	Pod length (mm)	Pod width (mm)
Accessions with low pod borer damage					
ICC 86111	370	8.6	54.0	1.80	0.79
ICC 93215	388	9.0	65.6	2.03	0.94
ICC 93216	443	9.2	82.7	1.84	0.87
ICC 93510	285	9.4	52.0	2.27	0.96
ICC 93515	299	9.4	72.9	2.30	0.89
Accessions with high seed yield plant^{-1}					
ICC 93055	487	18.1	87.4	1.69	0.78
ICC 93516	356	13.7	86.8	1.95	0.85
ICC 93216	443	9.2	82.7	1.84	0.87
ICC 93212	425	13.6	81.2	2.13	1.04
ICC 93041	384	14.6	80.5	2.20	1.05
Accessions with high pod length					
ICCV 16	307	14.5	59.7	2.33	0.97
ICC 93515	299	9.4	72.9	2.30	0.89
ICC 93510	285	9.4	52.0	2.27	0.96
ICC 126031	157	29.3	28.7	2.26	1.08
ICC 93509	276	20.8	64.6	2.24	1.09
Accessions with high pod width					
ICC 4973	405	11.2	69.5	1.98	1.18
ICC 93512	276	11.4	74.8	2.22	1.10
ICC 93034	279	25.0	48.2	1.85	1.10
ICC 93509	276	20.8	64.6	2.24	1.09
ICC 126031	157	29.3	28.7	2.26	1.08
Accession with highest pod borer damage					
Kouroush	141	40.6	15.6	2.08	1.00

Dry Areas (ICARDA), Aleppo, Syria, and state agricultural universities and six approved cultivars (GL769, GPF 2, PDG 3, C 214, PBG 1, and L 550) were evaluated in the field under unprotected conditions in a randomized complete block design with three replications. Each germplasm accession was accommodated in a single row plot of 4-m length. Rows were spaced at 50 cm, while plant to plant spacing was kept at 20 cm. Recommended crop production practices were followed to raise a good crop. Data on five competitive plants were recorded on number of pods per plant, number of pods damaged by pod borer, pod length (mm), pod width (mm), and seed yield per plant (g). Ten pods from each of the five plants were used to measure pod length and width. Mean data of five plants were used to determine the association of pod borer damage with other traits.

Five accessions—ICC 86111, 93215, 93216, 93510, and 93515—had less than 10% pods damaged by pod borer. Of these, the accession ICC 93216 also had considerably high seed yield (Table 1). Most of the accessions (48) were found to have 11-20% pod borer damage. The remaining 14 accessions had more than 20% damage. Highest (40.6%) pod borer damage was observed in accession Kouroush followed by ICC 93501 (38.9%), ICC 93051 (31.9%), and ICC 93056 (31%). The accession ICC 86111 had the lowest pod borer damage (8.6%) and high seed yield. Five accessions (ICC 93041, 93212, 93055, 93216, and 93516) had higher seed yield (>80 g plant^{1}) compared to other accessions (Table 1). Incidence of pod borer on these five accessions varied from 9.2% in ICC 93216 to 28.8% in ICC 93055. The accession ICCV 16 had the highest pod length (2.33 mm), while C 214 had the lowest pod length (1.34 mm). Four accessions, ICC 93515, 93510, 93512, and 93049 had higher pod length (2.17-2.30 mm) and low pod borer damage (9.4-11.4%) as compared to other accessions. The accessions ICC 4973 and ICC 93512 had higher pod width (1.18-1.10 mm) and comparatively low pod borer damage (11.2-11.4%) (Table 1). The pod borer damage was positively correlated to total number of pods (r = 0.36**) and pod length and pod width did not have any association with the pod borer damage.

The results demonstrated that the accessions ICC 93512, 93515, and 93212 are the most promising with higher seed yield and low pod borer damage. Further work is required on locating the genes responsible for low pod borer damage in such genotypes as ICC 86111 and search for possibilities of incorporating such genes to these three elite genotypes.

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Efficacy of Neem, Karanj, and Tobacco Formulations Against *Helicoverpa armigera* (Hubner) in Chickpea Crop

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Cultivated chickpea at Pantnagar (29°N 79°E) in northern India flowers and produces pods in March and April, when adult and larval activity of its major pest *Helicoverpa armigera* (Hubner) is at its peak causing up to 100% pod damage. Field trials with commercial neem (*Azadirachta indica* A. Juss) products, neem oil, and neem seed kernel water extract (NSKWE) have amply demonstrated that these materials are effective against gram pod borer (Sharma and Dahiya 1986). However, little systemic work has been done to study the effect of neem, karanj *(Pongamia glabra* Pierre), and tobacco formulations (nicotine sulphate) on pod damage, avoidable yield loss, grain yield, and cost benefit ratios of different formulations.

This study examined seven botanical insecticides including neem, karanj, and tobacco formulations in comparison with endosulfan in 1992-93 and 1993-94 at the Crop Research Centre, Pantnagar, for the control of pod borer damage on chickpea cultivar C 235. The crops were sown on 20 Dec in 1992 (harvested on 12 May 1993) and 13 Dec in 1993 (harvested on 4 May 1994). Experiments were laid out in a randomized block design with four replications in plots of 17 rows each 5-m length, with interrow spacing of 30 cm. All treatments consisted of three applications, the first at pod initiation

stage and second and third at 10 day intervals. Pod borer damage at maturity was assessed from the total pods of 20 plants per plot selected at random and yield data was from a net plot of 20.25 m^2 (the central 4.5 m of the 15 inner rows). The insecticide dosages tested are given in table 1 and formulations were sprayed using a high volume sprayer at 600 L ha^{-1}. The increase in grain yield was calculated according to the yield in treated plots compared to untreated plots.

Avoidable yield loss was calculated as percent yield loss in unprotected when compared to protected crop treatment as follows:

$$\text{Percent avoidable yield loss} = \frac{\text{Yield in protected crop} - \text{yield in unprotected crop}}{\text{Yield in protected crop}} \times 100$$

Table 1. Field efficacy and economics of plant products for the control of *H. armigera* in chickpea during 1992-93 and 1993-94.

Treatments, concentration (%)	Pod damage at maturity (%)	Grain yield (t ha^{-1})	Increase in grain yield over cont. (%)	Avoidable yield loss (%)	Inc. in grain yield over control (t ha^{-1})	Cost of Inc. grain yield (Rs)	Quantity of Ins./3 sprays ha^{-1} (Rs)	Cost of Ins. appli./3 sprays ha^{-1}**	Benefit: cost ratio
Neem products									
Green Mark, 0.4	48.8 (52.7)	0.98 (1.55)	390 (86.7)	79.6 (46.5)	0.78 (7.2)	6240 (5760)	7.2 L (7.2 L)	990 (990)	6.3 (5.8)
Neem guard, 0.4	53.7 (69.6)	0.52 (1.45)	160 (74.7)	61.5 (42.8)	0.32 (6.2)	2560 (4960)	7.2 L (7.2 L)	990 (990)	2.6 (5.0)
Achook, 0.4	65.1 (64.2)	0.29 (1.34)	45 (61.4)	31.0 (38.1)	0.09 (5.1)	720 (4080)	7.2 kg (7.2 kg)	990 (990)	* (4.1)
Neem oil, 2.0	50.7 (59.0)	0.62 (1.65)	210 (98.8)	67.7 (49.7)	0.42 (8.2)	3360 (6560)	36 L (36 L)	1710 (1710)	2.0 (3.8)
NSKWE, 5.0	62.2 (68.0)	0.38 (1.45)	90 (74.7)	47.4 (42.8)	0.18 (6.2)	1440 (4990)	90 kg seed (90 kg seed)	540 (540)	2.7 (9.2)
Karanj oil, 2.0	44.1 (52.4)	1.29 (1.55)	545 (86.7)	84.5 (46.5)	1.09 (7.2)	8720 (5760)	36 L (36 L)	1710 (1710)	5.1 (3.4)
Nicotine sulphate, 40 w/v,0.2	55.0 (51.4)	0.67 (1.39)	235 (67.5)	70.1 (40.3)	0.47 (5.6)	3760 (4440)	9 L (9 L)	1170 (1170)	3.2 (3.8
Controls									
Endosulfan, 35 EC, 0.07	40.2 (29.3)	2.12 (2.27)	960 (173.5)	90.6 (63.3)	1.92 (14.4)	15360 (11520)	3.6 L (3.6 L)	1036.8 (1036.8)	14.8 (11.1)
Untreated	81.7	0.2	-	-	-	–	-	–	–
Control	(70.3)	(0.83)	-	-	-	-	-	-	-
CD (0.05)	21.2 (23.4)	0.44 (0.57)							

Inc = Increased, Cont. = Control, Ins. = Insecticides, Appli = application, * = Negative value.

1. Spray solution @ 600 L ha^{-1}, 2. Average price of chickpea (1994). Rs 8000 t.

** = Cost of 1 Ins. Application = cost of Ins/ha + cost of 3 labour @ Rs 30 labour day^{-1}

Market cost of insecticide (1994): Green Mark, Neem guard and Nicotine sulphate Rs 100 L; Achook Rs 100 kg, Neem oil and Karanj oil Rs 40 L; Neem seed kernel Rs 3 kg; Endosulfan Rs 213 L. The data in the parenthesis indicate the value of 1993-94.

Benefit/cost ratio was calculated by comparison of the cost of protective sprays and net gain over the control treatments.

The data (Table 1) show that field application of 3 sprays of endosulfan against *H. armigera* in chickpea resulted in significant reduction in pod damage at maturity and increased grain yield in both years. The application of endosulfan, 0.07%, gave maximum protection with minimum pod damage 40.2% and 29.3% and highest grain yield 2.12 and 2.27 t ha^{-1} respectively. Pod damage at maturity varied from 44% to 65% with grain yield 0.29 to 1.29 t ha^{1} in treated plots in 1992-1993 as compared to 81.7% and 0.2 t ha^{-1} in untreated control plots. Similar trend was observed in 1993-94 with varied pod damage 51-70% and grain yield 1.34-1.65 t ha^{-1} as compared to 70% damage and 0.83 t ha^{-1} yield in untreated control plots. The treatment of crop with karanj oil during 1992-93 resulted in minimum pod damage, 44% with maximum grain yield, percent increase in grain yield over control and percent avoidable yield loss, i.e., 1.29 t ha^{-1}, 54.5% and 84.5% respectively among various bioproducts tested. In 1993-94, the plots treated with nicotine sulphate gave lowest pod damage, 51% but treatment with neem oil gave maximum grain yield, percent increase in grain yield over control and avoidable yield loss, i.e., 1.65 t ha^{-1}, 99% and 50% respectively followed by karanj oil and green mark.

The data on the economics of different treatments show that endosulfan gave the maximum benefit/cost ratio, 14.8 in 1992-93 and 14.1 in 1993-94. Among the botanicals tested, green mark gave highest ratio, 6.3 followed by karanj oil, 5.1 in 1992-93 and NSKWE, 9.2 followed by green mark, 5.8 in 1993-94.

Neem, karanj, and tobacco formulations, when tested under heavy pest pressure at Pantnagar as in these studies and even in the All India Pulse Project data cited by Lal et al. (1986) were less effective than endosulfan. Similarly, Rao et al. (1990) had reported that neem oil was not effective against *H. armigera* and resulted in less yield of cotton seed. Gupta et al. 1990 had reported that application of karanj oil 3% and 5% reduced the pod damage of *H. armigera* to <3% as compared to 7% in control. However, no significant effect on yield was recorded.

Though neem formulations are very effective against a number of insect pests but it did not give adequate control under high pest pressure of *H. armigera* in chickpea agroecosystem, therefore, cannot be recommended alone for control.

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Balanced Nutrient Management in Chickpea

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Despite the fact that optimum plant growth and crop productivity cannot be realized without adequate and balanced soil nutrient supplies, nutrient management in crops is frequently restricted to major fertilizer nutrients: nitrogen (N), phosphorus (P), and/or potassium (K). This is particularly true in low-input high-risk drought tolerant crops, like chickpea (*Cicer arietinum* L.), frequently grown under rainfed conditions in coarse-textured and/or low-fertility soils (Saxena 1987). In view of widespread micronutrient deficiencies found in calcareous soils in South Asia (Sillanpaa 1982, NFDC 1998) and the importance of the crop, a missing-element technique field experiment was carried out to determine the components of balanced nutrient management in chickpea.

This rainfed experiment was conducted at NARC, Islamabad (mean annual rainfall 1 082 mm) on Shujabad soil series (Typic Hapludalfs) with apparent multiple nutrient deficiencies according to soil tests. The surface soil (0-15 cm) had a loam texture (58% sand, 25% silt, and 17% clay), pH 7.9 (1:1, soil-H_2O), electrical conductivity 0.24 dS/m, $CaC0_3$ equiv. 9.2%, organic matter 0.7%, and hot water extractable B 0.24 mg kg^{-1}. The AB-DTPA extractable nutrient contents (mg kg^{-1}) in the topsoil were: $N0_3$-N, 0.5; P, 2.0; K, 76; Fe, 5.5, and Zn, 0.54. Thus, the field soil was apparently deficient in N, P, K, Zn (Soltanpour 1991), and B (Sakal et al. 1985). Total monthly rainfall and mean temperature during Jul 1991 to Jun 1992 are presented in Figure 1. Eight fertilizer treatments applied by broadcast before sowing of chickpea (cultivar CM-72) included: control (no fertilizer); all nutrients [i.e. 25 kg N ha^{-1} as urea (as starter N) + 75 kg P_2O_5 ha^{-1} as single superphosphate + 60 kg K_2O ha^{-1} as K_2SO_4 + four weekly foliar sprays of Fe as 1% solution of *Sequestrene* (Fe-EDDHA) + 10 kg Zn ha^{-1} as $ZnSO_4$ + 2 kg B ha^{-1} as H_3BO_3]; and all nutrients, except one at a time (i.e. N, P, K, Zn, Fe, or B) in the remaining six treatments. The crop was sown on 19 Nov 1991 and harvested on 28 May 1992. The experimental plots were 4 m long and 1.8 m wide, with six crop rows 30 cm apart. The crop was not affected by moisture stress, waterlogging or pest and disease problem. Moreover, it was well protected from birds and kept free from weeds. The experiment was laid out in a randomized complete block design with four replications. Grain yield was recorded at maturity.

Table 1. Chickpea grain yield as affected by fertilizer application in the missing-element technique field experiment. Values are means of 3 replications.

Nutrients applied	Grain yield (kg ha-')	Yield reduction over maximum (%)	Yield increase over control (%)	VCR[1]
Control (no nutrient applied)	1 110 c[2]	-45		
All Nutrients (N, P, K, Fe, Zn, and B)	2010a	-	81	7:1
All Nutrients - N	1982 a	-2	79	
All Nutrients - P	1 395 bc	-31	26	10:1
All Nutrients - K	1 800 ab	-10	62	
All Nutrients - Fe	1965 a	-2	77	
All Nutrients - Zn	1 400 bc	-30	26	17:1
All Nutrients - B	1390 bc	-31	25	20:1
LSD (0.05)	509			

1. VCR (Value: Cost Ratio) is the ratio between value of additional grains produced to the money spent on fertilizer. (Prices per kg: Chickpea, Pakistani Rs 20.00; P_2O_5, Rs 20.72; Zn, Rs 70.00; B, Rs 318.00).
2. Means followed by the same letters) within the column are not significantly different from each other at $P < 0.05$ according to Duncan's Multiple Range Test.

Application of all the macro- and micronutrients together resulted in an 81% increase in grain yield over control ($P < 0.05$). No decrease in grain yield over the maximum (obtained with all nutrients), however, occurred in the treatment without starter N (-N) (Table 1), presumably because of effective native *Rhizobium* population in the NARC soils (Aslam et al. 2000). Similarly, no yield reduction was observed without Fe application to this Fe-efficient chickpea cultivar CM-72 (Rashid and Din 1993). Also, chickpea plants did not exhibit symptoms of *iron chlorosis* in the control and -Fe treatments. A statistically non-significant yield reduction of 10% was observed without K application (Table 1). Yield reduction without P, B, and Zn was, however, rather drastic: 31% each without P or B and 30% without Zn (<0.05; Table 1). The economics of applying these nutrients (Table 1) suggests that using these fertilizers in chickpea would increase farmer income substantially. Thus, fertilization for P, B, and Zn was crucial for harvesting optimum crop yield.

Despite being more efficient than cereals in utilizing native soil P under deficient conditions because of its mycorrhizal and rhizosphere-acidifying root system, chickpea grown in P-deficient soils responds well to P fertilization (Rashid and Bughio 1993). Reductions in chickpea grain yield due to deficiency of B and/or Zn, however, are rarely reported. The B requirement in growth media for pollen germination and growth is high for many species, and its deficiency in chickpea causes flower abortion and pod set failure (Srivastava et al. 1997).

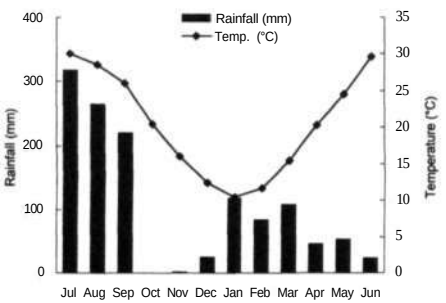

Figure 1. Monthly total rainfall and mean temperature at NARC, Islamabad, Pakistan during Jul 1991 to Jun 1992 (source: Dr Muhammad Khan, Water Resources Research Institute, National Agricultural Research Center, Islamabad, personal communication).

The crop is also more sensitive than cereals to deficiency of Zn (Tiwari and Dwivedi 1990). Thus, yield reductions without application of these micronutrients in the present study are understandable as soil testing had indicated deficiency of N, P, K as well as of B and Zn.

Chickpea in many countries is frequently grown in coarse-textured soils that are low in available micronutrients. Therefore, fertilizer application in the crop must ensure adequate supply of micronutrients, along with major nutrients. Alternatively, adoption of micronutrient-efficient crop genotypes is suggested in the deficient fields. Multilocation on-farm trials are planned, to assess the need for macro- and micro-nutrient fertilization in major chickpea growing areas of the country.

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Promising Chickpea Ideotype for Higher Plant Density

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Chickpea is generally planted at a plant density of 33 plants m^2 (30 cm row to row spacing, and 10 cm plant to plant spacing). However, Jeswani (1986) stressed the need to define ideotypes in pulses to improve the harvest index for major breakthrough through changes in plant type by reducing their spreading, indeterminate, and bushy habit. Siddique et al. (1984) proposed chickpea ideotype for enhancement of yield comprising not more than two branches when sown at high plant density. Similar ideotype approach was suggested to overcome the genetic limits of chickpea productivity by introduction of major morpho-physiological changes such as compact and erect plant habit, open and upright canopy, responsiveness to higher density planting, better management, and input conditions (Dahiya et al. 1990).

Based on chickpea ideotype concept, through recombination breeding and utilizing E100 ym, a spontaneous brachytic mutant as donor for erectness and compactness, a large number of promising breeding lines for higher seed yield under late planting high input conditions for rice-chickpea or cotton-chickpea sequential cropping has been developed (Fig. 1). These progenies were erect and compact in growth habit (for higher density planting), with strong and reasonably tall stem (for better competition against weeds and lodging resistance), few but erect secondary and later order branches (for better light interception and air exchange of canopy). These promising chickpea advance breeding lines, particularly the genotype H96-99, recorded comparable seed yield against check varieties at normal density planting (33 plants m^2). However, they showed significant seed yield superiority under high density planting of 50 plants m^2 (Table 1), when evaluated with twelve genotypes with three replications in randomized block design in two sets with same date of sowing (23 Nov 1998). The plot size sown was 9.60 m^2 for both spacing treatments. The statistical analysis was done by combining the two factors (plant density x genotypes) as suggested by Campbell, 1978 (Table 2).

These chickpea ideotypes showed higher seed yield of about 4 t ha^{-1} under high density planting and are also found suitable for mechanical harvesting as the fruiting zone started at about 20 cm from base. Therefore, these

Table 1. Performance of advance breeding lines developed on ideotype approach for higher density planting.

	Genotype				
Character	H96-26	H96-99	C 235(Ch)	H86-18(Ch)	CD at 5%
Plant height (cm)	69.93	81.13	46.98	68.87	
Number of primary branches	5.27	5.33	4.07	5.02	
Number of secondary branches	9.87	9.98	14.86	12.72	
Canopy spread (cm)	16.27	19.67	29.89	25.32	
Initiation of fruiting nod (cm)	23.47	22.60	28.87	27.97	
Number of pods ($plant^{-1}$)	63.27	69.92	58.82	52.56	
Number of seeds (pod^{-1})	1.22	1.26	1.34	1.28	
Seed yield (kg ha^{-1}) normal density	2421.00	2627.00	2659.00	2460.00	261.52
Seed yield (kg ha^{-1}) higher density	3981.00	3843.00	3033.00	2870.00	197.48

CD (5%) for comparing seed yield means of plant densities x genotypes: 792.91 kg ha^{-1}.

Table 2. ANOVA for combined two factor (plant density and genotype) analysis.

Source	d.f	S.S.	M.S.S	F-value	
Plant density	1	188.31	188.31	9.67	Significant
Genotypes	11	1419.06	129.00	6.63	Significant
Plant density x genotypes	11	214.14	19.47	5.11	Significant
Replications	2	14.15	7.08		
Residual/Error	22	83.85	3.81		
Total			1919.51		

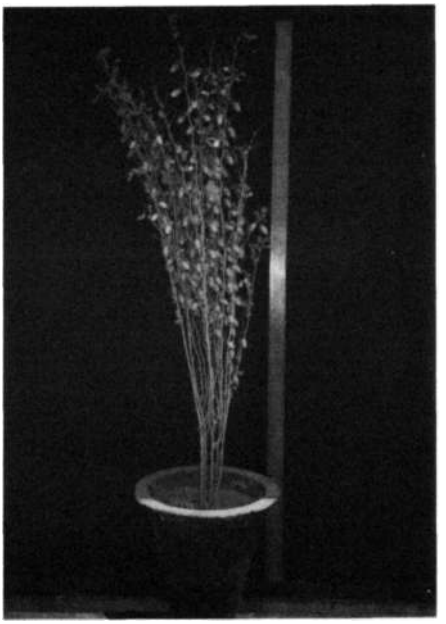

Figure 1. H96-99; A chickpea ideotype for high density planting (Field-grown representative plant potted at maturity).

ideotypes were found to be suitable and promising for better input conditions of moisture and soil fertility under late planting conditions of rice-chickpea or cotton-chickpea sequential cropping systems as these will not produce excessive vegetative growth.

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Shoot Regeneration from Internode Derived Callus of Chickpea (*Cicer arietinum* L.)

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Several problems of improved chickpea can substantially benefit from biotechnological intervention. A basic requirement is the availability of procedures for *in vitro* regeneration. In chickpea, proliferation of shoot buds from different meristematic explants has been reported (Bajaj and Dhanju 1979, Kartha et al., and Rao and Chopra 1989). Considerable advancement in tissue culture systems for large seeded legumes has been achieved (Baker and Wetzstein 1992). Very few reports are available on regeneration of multiple shoots via callus induction and organogenesis in chickpea which this report describes.

Mature seeds of Nabin were grown aseptically and internode explants were excised from 2 week old sterile seedlings for callus induction. Callus was induced on MS and B5 media and incubated in dark and light at 25 ± 1°C. B5 medium supplemented with 3 mg L^{-1} 2, 4 D, and 3 mg L^{-1} BAP, or 3 mg L^{-1} NAA, and 3 mg L^{-1} BAP and dark incubation was found best for producing organogenic callus. After 5 weeks the calluses were transferred to MS basal medium supplemented with different combinations of kinetin and IAA and incubated in 16 h photoperiod for shoot formation. The pH of the mediums were adjusted to 5.7 before autoclaving.

Callus initiation was observed from cut surface of the explants within 10-12 days of incubation. Horizontally oriented explants produced callus more rapidly than those which were placed vertically and by the 4th week almost every explant turned into a mass of callus. Globular structure were seen on these calluses. During the 4th week some globular structures appeared on the

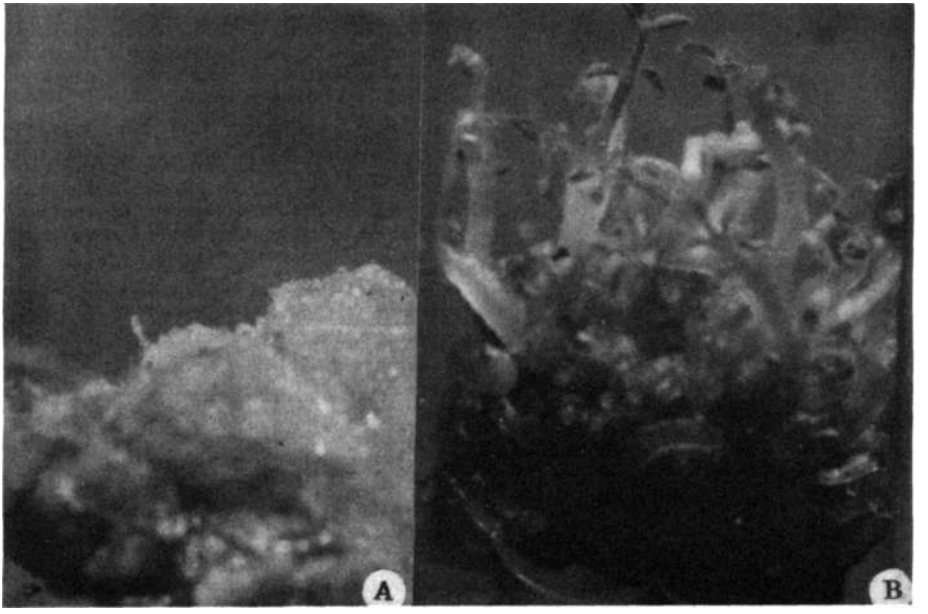

Figure 1. Adventitious shoot organogenesis from internode explants of *C arietinum*. (A) Formation of globular like structure on the upper surface of callus. (B) Multiple shoot formation on callus when subcultured on to shoot regeneration medium.

Table 1. Response of subcultured calluses obtained from internode explants of chickpea to Kinetin and IAA in MS medium.

Growth regulators	% of calluses formed shoots	No. of shoots per culture	Shoot length (cm)
KIN 1 + IAA 1	50	4	3.00
KIN 2 + IAA 1	30	4	5.00
KIN 3 + IAA 1	20	3	4.00
KIN 4 + IAA 2	10	2	6.00
KIN 1 + IAA 2	-	-	-
KIN 2 + IAA 2	60	15	2.50
KIN 3 + IAA 2	50	10	3.00
KIN 4 + IAA 2	30	5	3.50

upper surface of calluses (Fig. 1) and morphological changes were observed after 5 weeks in culture when the globular structure grew into adventitious shoot buds. The shoot buds developed normally when the explants were subcultured in MS medium containing different combinations of Kinetin and IAA (Table 1).

On transfer to MS medium without any growth regulator or with only kinetin (1-4 mg L^{-1}) light green calluses become dark green or blackish and friable but no further morphogenic changes were noticed. At the end of the 5th week of subculture partial browning and darkening of external portion of calluses started and consequently they became necrotic. When the calluses were transferred to a medium containing Kinetin (1-4 mg L^{-1}) and IAA (1-2 mg L^{-1}) shoot proliferation started within 2 weeks of subculture. Highest percentage (60%) of calluses producing shoots and maximum number (15) of shoots per culture were obtained on medium containing 2 mg L^{-1} kinetin and 2 mg L^{-1} IAA (Fig. 1).

In the present investigation it was observed that 2, 4-D without cytokinin could induce calluses but for better proliferation a cytokinin in combination with 2, 4-D was required. It was also observed that length of shoots decreased with the increase in shoot number. Similar observation was made earlier (Kartha et al. 1981, Rao and Chopra 1989, and Islam and Riazuddin 1993).

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Breeding/Genetics

Gene Symbols in Pigeonpea

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Pigeonpea (*Cajanus cajan* (L) Millsp.), also called as 'red gram' in India, 'Nandolo' in Malawi, 'Gandul' in Puerto Rico, 'Mu Dou' in China and 'Quinchocho' in Venezuela, is an important pulse crop of the semi-arid tropical regions of the Indian subcontinent, Africa, and the Caribbean. A large genetic variation exists within this species for different quantitative and qualitative traits (Remanandan 1990, Saxena and Sharma 1990). A number of genetic studies have been conducted in the past and gene symbols assigned. In this paper an attempt has been made to compile information on gene symbols for a number of traits. The studies conducted by different authors have been grouped together appropriately and we have not made any attempt to equate them or to reinterpret the published data. A compilation of originally assigned gene symbols in pigeonpea and in some interspecific crosses, involving pigeonpea and its wild relatives, is respectively summarized in Table 1 and 2.

This compilation is the first such attempt in pigeonpea and the information will be useful in assigning gene symbols in future. Also, it will avoid duplication of the gene symbols. In most cases the information has been obtained directly from the published articles and attempts have been made to reproduce them in the original form. However, the authors could not acquire two research papers (marked with *) and the information has been cited using other related publications. The authors would appreciate comments from readers regarding any errors of content and/or omission. In this review an attempt has also been made to provide information about genetic variation considered for study, the details about the genetic control of various phenotype(s) is not discussed for the sake of brevity and for such details the readers are advised to refer the original articles.

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Table 1. Summary of gene symbols in pigeonpea.

Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Flower colour					
Yellow, white	Yellow	49:15	W_1, W_2, I	Patil and D'Cruz 1962	W_1 and W_2 duplicate genes produce white flowers. I inhibits and produces yellow flowers.
Creamy white with red veins on back of standard, yellow-red veins on back of standard	Yellow with red veins on back of standard	3:1	Y fl	Patil et al. 1972	
Yellow, creamy white	Yellow	207:49	$Yvsd_{a1}$, $Yvsd_{a2}$, $Yvsd_{a3}$, $Yvsd_{b2}$	Jambhale et al. 1978	
Yellow, yellow with red veins	Yellow with red veins	45:19	$Rvds_a$, $Rvds_b$, $Rvds_c$	Chopde et al. 1979	
White, yellow	Yellow	49:15	Wfl_1, Wfl_2, I-Wfl	Kolhe and Nayeem 1977	
Colour of ventral surface of standard petal					
Yellow, pale yellow	Yellow	3:1	Yvs	D'Cruz and Deokar 1970a	
Orange yellow with diffused purple base, yellow	Orange yellow with diffused purple base	9:7	$Oyvs_1$, $Oyvs_2$	Deokar and D'Cruz 1972a	$Oyvs_2$ pleiotropic for colour of dorsal surface of standard and purple spotting on white seed
Yellow, lemon yellow	Yellow	13:3	Llt, I-Llt	Deokar and D'Cruz 1971a	I-Llt common to colour of dorsal surface of standard and to colour of veins on dorsal surface. Also pleiotropic action on pod colour (duplicate action with gene Blp of pod Colour)
Yellow, pale yellow	Yellow	3:1	Yvs	D'Cruz et al. 1971c	
Yellow, lemon yellow	Yellow	162:94	Yvs_2, Yvs_{a2}, Yvs_{c2}, Yvs_{d2}	Deokar et al. 1972c	The subscript of 2 has been to three out of 4 genes because these three have duplicate complemen tary action, any two of the three are effective
Yellow, orange yellow	**Orange yellow**	**3:1**	**Oyvs**	**Chaudhari and Thombre 1983**	

Contd.

Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Red, yellow	Red	3:1	Pds	Narkhede et al. 1980	
Cream, white	Yellow	9:7	Yvs_p, Yvs_b	Ghatge and Kolhe 1985	
Colour of dorsal surface of standard petal					
Orange yellow with purple veins and purple patch at the base, yellow	Orange yellow with purple veins and purple patch at the base	3:1	$Oyvs_a$	Deokar and D'Cruz 1972a	Common with one of the two genes for colour of ventral surface of standard
Yellow, light purple with purple base	Yellow	13:3	Llt, I-Llt	Deokar and D'Cruz 1971a	
Yellow with deep red veins and base diffused red, yellow with light red veins	Yellow with deep red veins, and base diffused red	3:1	Rvbds	Shinde et al. 1972	
Orange yellow, yellow	Orange yellow	45:19	$Oyds_a$, $Oyds_{a1}$, $Oyds_{a2}$	D'Cruz et al. 1971b	
Yellow with purple veins, yellow, orange yellow	Yellow with purple veins, orange yellow	9:7	$Rvds_1$ $Rvds_2$, $Oyds_a$ $Oyds_b$	D'Cruz et al. 1973	
Yellow red vein, yellow	Yellow red vein	183:73	Rvds, I-Rvds, A-I-$Rvds_1$, A-I-$Rvds_2$	Marekar and Chopde 1985	
Yellow, yellow with purple veins	Yellow with purple veins	3:1	Rvds	D'Cruz et al. 1974	
Purple, diffused with deep purple veins	Yellow with faint purple veins	1:2:1	Pds	Narkhede et al. 1980	
Colour of vein of dorsal surface of standard petal					
Purple, yellow	Purple	39:25	Llt, I-Llt, A-I-Llt	Deokar and D'Cruz 1971a	
Dark red, Purple red	Dark red	21:43	Drv, I-Drv	Chaudhari and Thombre 1975	
Yellow, red	Red veins	9:7	$Rvdss_a$, $Rvdss_b$	Chaudhari and Thombre 1977	
Yellow with purple vein Yellow with self coloured veins	Yellow purple veins	15:1	$Pvds_1$, $Pvds_2$	Deokar et al. 1971b	

Contd.

Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Yellow with purple veins, yellow	Yellow with purple veins	3:1	Rvds	D'Cruz et al. 1974	
Yellow, red	Red	9:7	$Rdvds_a$, $Rdvds_b$	Kolhe et al. 1972	
Yellow, red	Red	9:7	$Rdvds_b$ $Rdvds_b$	Patil 1970	
Red, yellow	Yellow	13:3	Rvds, I-Rvds	Ghatge and Kolhe 1985	
Calyx colour					
Pigmented, yellow	Pigmented	9:7	A, B	Singh and Srivastava 1981	
Partially cleistogamous flower					
Normal, partially cleistogamous	Normal	3:1	Pct	Saxena et al. 1992	
Normal, closed	Normal	15:1, 3:1	Clf 1, Clf 2	Mehetre et al. 1992	Mutant form governed by duplicate genes
Response to photoperiod					
Sensitive, insensitive	Sensitive	3:1	PS_1 PS_2, PS_1	Saxena 1981	PS_3, >PS_2, >PS_1. Therefore, 3:1 every time
Flowering habit					
Early, late	Early	45:19	Efl_a, Efl_b, Efl_{a2}	Marekar 1982	
Early, late	Early	45:19	Efl_b, Efl_{a2},Efl_{a2}	Marekar and Chopde 1985	
Male sterility					
Fertile, sterile	Fertile	3:1	ms_2	Saxena et al. 1983	
Fertile, sterile	Fertile	3:1	ms_1	Reddy et al. 1978	
Fertile, sterile	Fertile	15:1	$Stfl_1$, $Stfl_2$	Mehetre et al. 1989	Duplicate genes
Pod colour					
Maroon blotched, green	Maroon blotched	15:1	$Gppd_1$, $Gppd_2$	D'Cruz and Deokar 1970a	
Maroon blotched + green with blackish purple streaks, maroon blotched + green with blackish purple shades	Maroon blotched with blackish purple all over pod	15:1	Blp, I-Llt	Deokar and D'Cruz 1971a	Unripe pod colour

Contd.

Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Maroon blotched red grained, maroon blotched round leaf	Maroon blotched	195:61	Blp_1, Blp_2, I-Blp, A-I-Blp	Deokar et al. 1972b	Unripe pod colour
Purple, green with purple shade	Purple	9:3:4	Gpstpd, Gpshpd	Deokar et al. 1971b	
Green with purple streaks, green	Green with purple streaks	3:1, 3:1	Gppd	D'Cruz et al. 1971b D'Cruz et al. 1971c	
Dark purple, purple streaks	Dark purple	39:25	Ppd, I-Ppd, A-I-Ppd	D'Cruz et al. 1974	
Purple with green streaks, green with Purple streaks	Purple with green streaks	117:139	$PGPD_a$, $PGPD_b$, I-$PGPD_{ab}$, A-I-$PGPD_{ab}$	Deokar et al. 1972c	
Green with black colour diffused, green with black color in streaks	Green with black color diffused	3:1	Bldpd	Shinde et al. 1972	
Green with purple streaks, green with black streaks	Green with black streaks	3:1	Bl_{pd}	D'Cruz et al. 1970b	
Greenish black, maroon blotched	Greenish black	3:1	Blp	Patil and D'Cruz 1965	Unripe
Greenish black, maroon blotched	Greenish black	3:1	Bl_{pd}	Patil 1970	Unripe
Green, black streaked	Black streaked	45:19	$Gbpd_a$, $Gbpd_{a2}$, $Gbpd_{a3}$	Jambhale et al. 1978	Duplicate complementary
Plain, maroon	Plain	3:1	Bpd	Nayeem 1978	
Plain, maroon	Plain	3:1	P_{pd}	Kolhe and Nayeem 1977	
Pod development					
Normal, open carpel	Normal	3:1	Cd_1	Saxena et al. 1988a	
Seed colour					
Reddish brown, white	Reddish brown	9:7	$Brsd_a$, $Brsd_b$	D'Cruz and Deokar 1970a	
Blackish purple, white	Chocolate	3:6:3:1:2:1	$Oyvs_a$, Brsd	Deokar and D'Cruz 1972a	
Reddish brown, white	Reddish brown	9:7	I.lt, Brsd	Deokar and D'Cruz 1971a	
Reddish brown, white	Reddish brown	3:1	Rsd	Deokar et al. 1972b	
Brown, white	Brown	3:1	Brsd	Deokar et al. 1971b	

Contd.

Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Brown, white	Brown	3:1	Brsd	D'Cruz et al. 1974	
Blackish purple, white	Blackish purple lighter than parent	9:3:3:1	Brsd, Wpsd	D'Cruz et al. 1971b	
Brown, white, blackish purple	Brown Blackish purple	9:7 9:3:3:1	Brsd, Wpsd $Brsd_a$, $Brsd_b$	D'Cruz et al. 1973	
Reddish brown, white	Reddish brown	63:1	$Brsd_1$, $Brsd_2$, $Brsd_3$	Patil et al. 1972	
Red, white	Red	9:7	Rsd_a, Rsd_b	Marekar and Chopde 1985	
Black, white, brown	Brown	39:13:9:3	$Brsd_1$, $Brsd_2$, $Brsd_3$	Singh and Srivastava 1981	
Brown, white	Brown	39:25	Br_{sd}, $Br_{sd}I$, $Br_{sd}IA$	Patil 1970	
Brown, purple	Purple	3:1	Plsd	Chaudhari and Thombre 1975	
Pinkish white, brown	Brown,	9:7	$Brsd_a$, $Brsd_b$	Chaudhari and Thombre 1977	
Brown, fawn	Light brown	9:3:4	Brsd, Fsd	Ghatge and Kolhe 1985	
Seed size					
Bold, small	Bold	27:37	Bsd_a, Bsd_b, Bsd_c	Marekar 1982	
Bold, small	Bold	129:127	Bsd, I-Bsd, A-I-Bsd_a A-I-Bsd_b	Marekar and Chopde 1985	
Growth habit					
Determinate, indeterminate	Indeterminate	13:3	Id, D	Waldia and Singh 1987a	Id had an inhibitory effect on the gene for determinate habit, D
Determinate, indeterminate, semi-determinate	Determinate, indeterminate or semi-determinate	3:1 3:1 12:3:1	Dt_1 Dt_{2a}	Gupta and Kapoor 1991	two epistatic genes
Plant type					
Erect, creeping	Erect	3:1	Egr	Deokar and D'Cruz 1971a	
Creeping, prostrate	Erect with spreading branches	45:9:10	Cgr_a, Cgr_{b1}, Cgr_{b2}	Deokar et al. 1971b	

Contd.

Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Erect, prostrate	Erect	54:10	Egr_{a1}, Egr_{a2}, Egr_{a2}	D'Cruz et al. 1974	The subscript 2 indicates that any two of the three are necessary for production of erect which is dominant
Erect, creeping	Erect	13:3	Cgr I-Cgr	Shinde et al. 1972	
Erect, creeping	Erect	13:3	Cgr, I	Patil and D'Cruz 1965	
Erect, creeping	Erect	13:3	C_{gr}, I	Patil 1970	
Erect, creeping	Erect	3:1	Egr	Chaudhari and Thombre 1975	
Erect, semi-erect	Erect	54:10	Egh_{a1}, Egh_{a2}, Egh_{a3}	Chaudhari and Thombre 1977	
Plant height					
Tall, dwarf	Tall	3:1	Tsta	D'Cruz et al. 1971a	
Tall, dwarf	Tall	49:15	Tht, I-Tht_2, I-Tht_{2x}	Marekar 1982	
Tall, dwarf	Tall	165:91	Tht, I-Tht_x, I-Tht_y, A-I-Tht	Marekar and Chopde 1985	One basic, two inhibitory complementary and one anti-inhibitory gene
Tall, dwarf	Tall	3:1	d	Sen et al. 1966	
Tall, dwarf	Tall	3:1	t_2, t_3^b	Saxena et al. 1989	
Tall, dwarf	Tall	15:1	t_1, t_2	Waldia and Singh 1987b	
Tall, dwarf	Tall	3:1	t_4, t_5	Gupta et al. 1992	
Stem colour					
Purple, green	Purple	3:1	Pst	D'Cruz and Deokar 1970a	
Purple, green	Purple	45:19	Pst_a, Pst_b, Pst_c	Deokar and D'Cruz 1972a	
Purple, green	Purple	3:1	Pst	D'Cruz et al. 1971a	
Purple, green	Purple	3:1	Pst	D'Cruz et al. 1971b	
Purple, green	Purple	3:1	Pst	D'Cruz et al. 1974	
Purple, green	Purple	3:1	Pst	D'Cruz et al. 1971c	

Contd.

Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Purple, green	Purple	45:19	Pst_a, Pst_{b1}	Nayeem 1978	
Purple, green	Purple	9:7	Pst_a, Pst_b	Kolhe and Nayeem 1977	
Purple, green	Purple	3:1	Pst	Narkhede et al. 1980	
Stem surface					
Corky, smooth	Smooth	13:3	sm, Ck	Saxena et al. 1988b	Dominant form of sm masks the expression of Ck allele, resulting in smooth surface
Straight, wavy	Straight	45:19	$Strst_a$, $Strst_{b1}$, $Strst_{b2}$	Marekar 1982	One complementary and two duplicate complementary genes
Branching habit					
Spreading, erect	Spreading	3:1	Sbr	D'Cruz and Deokar 1970a	
Spreading, erect	Spreading	3:1	Sbr	Deokar and D'Cruz 1972a	
Spreading, erect	Erect with spreading branches	54:10	Sbr_a, Sbr_b, Sbr_{ab}	D'Cruz et al. 1971c	
Spreading, erect	Spreading	9:7	SBR_a, SBR_b	Deokar et al. 1972c	
Spreading, erect	Spreading	3:1	Sbr	D'Cruz et al. 1971b	
Spreading, erect	Spreading	3:1	Sbr	Kolhe et al. 1972	
Spreading, erect	Erect	111:145	Sbt, A-l-sbr_a, A-l-sbr_b, A-l-sbr_c	Marekar and Chopde 1985	
Close, semi-spreading	Close	63:193	$Clbr_a$, $Clbr_b$, l-$clbr_c$, l-$clbr_d$	Marekar 1978	
Spreading, erect	Spreading	9:7	Sbr_a, Sbr_b	D'Cruz et al. 1970b	
Spreading, erect	Spreading	9:7	Sbr_a, Sbr_b	Nayeem 1978	
Semi-erect, spreading	Spreading	243:13	Sbr_a, Sbr_b,Sbr_c, Sbr_d	Chaudhari and Thombre 1983	
Spreading, erect	Spreading	3:1	Sbr	Narkhede et al. 1980 and Ghatge and Kolhe 1985	
Spreading, semi-spreading	Semi-spreading	27:37	$Ssbr_a$, $Ssbr_b$, $Ssbr_c$	Chopde et al. 1979	
Close, erect	Close	21:43	Clbr, l-$Clbr_a$, l-$Clbr_b$	Marekar 1982	

Contd.

Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Leaflet shape					
Lanceolate, obcordate	Lanceolate	3:1	Llt	D'Cruz and Deokar 1970a	Pleiotropy with wing shape, wing position, keel shape, habit of keel
Lanceolate, obcordate	Lanceolate	3:1	Llt	Deokar and D'Cruz 1972a	Pleiotropic effect with wing shape, wing position, keel shape, habit of keel
Lanceolate, round	Lanceolate	3:1	Llt	Deokar and D'Cruz 1971a	Common to the two genes governing colour characters of standard petal. At the same time it showed complementary action with the gene for seed colour
Lanceolate, obcordate	Lanceolate	3:1	Llt	D'Cruz et al. 1971a	Pleiotropic effect with wing shape, wing position, keel shape, habit of keel
Lanceolate, round	Lanceolate	3:1	Llt	Deokar et al. 1972b	Linkage with gene for seed coat colour
Lanceolate, obcordate	Lanceolate	3:1	Llt	D'Cruz et al. 1971b	Linkage with genes for stem colour and leaf thickness
Lanceolate, obcordate, round	Round, lanceolate indifferent crosses	3:1 3:1	Llt, llt, llt	D'Cruz et al. 1973	
Lanceolate, obovate	Lanceolate	3:1	Llt	Patil and D'Cruz 1965	Linked with genes for growth habit and unripe pod colour. First linkage group reported
Lanceolate, obovate	Lanceolate	3:1	Llt	Patil 1970	
Lanceolate, obcordate	Lanceolate	3:1	Llt	Marekar 1978	Linked with one of the two complementary genes of branching habit
Lanceolate, round	Lanceolate	39:25	Llt, I-Llt, A-I-Llt	Chaudhari and Thombre 1977	

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Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Lanceolate (pointed apex), obcordate (depressed apex)	Oval (blunt apex)	9:3:4	Llt, Obclt	Patil and Deokar 1980	One of the two genes shows supplementary gene action
Round, obcordate connate	Obovate (oblong obovate)	27:9:9:9:3:3:4	Llt, Rlt, Clt	Ghatge and Kolhe 1984	
Obovate, lanceolate	Lanceolate	3:1	Llt	Nayeem 1978	
Lanceolate, obcordate	Lanceolate	3:1	Llt	Chopde et al. 1979	
Obcordate, lanceolate	Oblong	27:21:16	Llt, $Oblt_a$, $Oblt_b$	Jambhale et al. 1978	One basic and two complementary genes
Leaflet number					
Trifoliate, multifoliate	Trifoliate	183:73	Tf, I-Tf, A_1-I-Tf, A_2-I-Tf	Patil et al. 1972	A_1 and A_2 duplicate genes having anti-inhibitory effects
Trifoliate, multifoliate	Trifoliate	189:67	Tf, Tf_{a1}, Tf_{a2}, Tf_{c3}	Marekar 1982	
Trifoliate, multifoliate	Trifoliate	45:19	Tf_a, Tf_{b1}, Tf_{c1}	Marekar and Chopde 1985	
Leaf thickness					
Thick, thin	Thick	3:1	Dg lt	D'Cruz et al. 1971c	Same gene for leaf colour
Thin, thick	Thin	3:1	Tn lt	D'Cruz et al. 1971b	Linked with genes for leaflet shape and stem colour
Leaflet base					
Broad, narrow	broad	9:7	$Bdlb_a$, $Bdlb_b$	Kolhe et al. 1972	One of the genes along with the gene for leaf apex (Llt) shows duplicate gene action for the production of petiolule
Leaflet apex					
Obtuse, acute, retuse	obtuse	117:75:64	Alta, Olta, I-Olta, A-I-Olta	D'Cruz et al. 1971c	
Notchless, notched	Notchless	3:1	Llt	Kolhe et al. 1972	Pleiotropic effect on keel shape, keel habit and type of inflorescence
Round, pointed	Pointed	3:1	Llt	Nayeem 1978	

Contd.

Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Pointed, depressed	Blunt	9:3:4	Llt, Obclt	Patil and Deokar 1980	
Petiolule					
Present, absent	Present	15:1	Bdlb, Llt	Kolhe et al. 1972	
Leaf colour					
Light green, dark green	Light green	3:1	Dg lt	D'Cruz et al. 1971c	Same gene for leaf thickness
Dark green, light green	Light green	3:1	Lglt	Ghatge and Kolhe 1985	
Petiole length					
Long, short	Long	3:1	Lpt	D'Cruz and Deokar 1970a	
Long, short	Long	3:1	Lst_a	Deokar and D'Cruz 1972a	Represents one of the two genes governing stipel length
Long, short	Long	15:1	Lpt_1, Lpt_2	D'Cruz et al. 1971a	
Stipel length					
Long, short	Long	3:1	Lst	D'Cruz and Deokar 1970a	Closely linked with genes for stem colour and petiole length
Long, short	Long	9:7	Lst_a, Lst_b	Deokar and D'Cruz 1972a	
Mutant gigas leaf					
Normal, gigas	Normal	3:1	Nh, nh	Pokle 1976	Pleiotropic action
Disease resistance					
Alternaria susceptible, resistant	Susceptible	3:1	al_1	Singh et al. 1988	
Alternaria susceptible, resistant	Susceptible	3:1	abr_1	Sharma et al. 1987	
Sterility mosaic susceptible, resistant	Susceptible	43:21 13:3	Sv_1, Sv_2 sv_3, sv_4	Singh et al. 1983	Sv_1 and Sv_2 showed duplicate dominant epistasis and sv_3 sv_4 showed duplicate recessive epistasis for resistance
Phytopthora susceptible, resesistant	Resistant	3:1	Pd_1	Sharma et al. 1982	
Wilt resisistant, susceptible	Susceptible	3:1	pwt_1	Jain and Reddy 1995	

Table 2. Summary of gene symbols in interspecific crosses.

Character	Variation studied	F_1 phenotype	F_2 ratio	Gene symbols	References	Remarks
Strophiole	Present, absent	Present	13:3	NS, SDI	Reddy et al. 1981	
Strophiole	Present, absent	Present	15:1	SS_1, SS_2	Pundir and Singh 1985	Duplicate gene action
Seed mottling	Present, absent	Present	9:7	Msd_1, Msd_2	Reddy et al. 1981	
Twining nature	Twining, non-twining	Non-twining	13:3	I, T	Pundir and Singh 1985	
Pod surface	Hairy, non-hairy	Hairy	3:1	Hp	Pundir and Singh 1985	
Plant type	Erect, spreading	Intermediate	1: 1: 14	Eg_1 Eg_2	Pundir and Singh 1985	2 genes partial dominance
Seed colour	Black, orange	Grey	1:2:1	Osc	Pundir and Singh 1985	Partially dominant
Leaflet shape	Lanceolate, obovate	Intermediate	1:2:1	L_1	Pundir and Singh 1985	Partially dominant

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Response of Pigeonpea Hybrid PPH 4 to Varying Plant Densities

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Recently, a short duration pigeonpea hybrid PPH 4 has been developed and released for cultivation in Punjab, India. Generally, the spatial requirements of pigeonpea may vary considerably depending upon the growth rhythm of the genotypes, agronomic manipulations, and agro-climatic conditions of the region. The recommended spacing for short- and extra-short-duration varieties having erect and semi-spreading growth is 50 x 25 cm (8 plants m^2) in the State (PAU 1995). But the new hybrid has vigorous plant growth than the earlier released varieties (Verma et al. 1994). Therefore, a study was undertaken to workout the optimum plant density of PPH 4 to obtain higher productivity.

Field trials were conducted at the Punjab Agricultural University, Ludhiana (30°56'N, 75°52'E, 244 m altitude) in 1993 and 1994 under irrigated conditions. The soil of the experimental site was loamy sand having pH 8.2, low in organic carbon (0.29%) and available nitrogen (108 kg N ha^{-1}), medium in phosphorus (15.1 kg P ha^{-1}) and potash (208 kg K ha^{-1}). In 1993, PPH 4 (hybrid; and cultivar AL 201 were compared at seven plant densities (30 x 15, 40 x 15, 60 x 15, 50 x 25, 67.5 x 20, 67.5 x 25 and 67.5 x 30 cm) in a split plot design with three replications. In 1994, PPH 4, AL 201, and H 82-1 were evaluated with plant densities followed in 1993 with the addition of 50 x 15 cm and deletion of 67.5 x 20 cm spacing. The cultivars and hybrids were allocated in the main plots and plant densities in the subplots. The crop was sown on June 7, and 10 respectively during the two consecutive years with pre-sowing irrigation. Basal doses of 15 kg N and 40 kg P_2O_5 ha^{-1} were drilled. A seed rate of 15 kg ha^{-1} was used for sowing and a required plant stand was maintained about 30 DAS. Two hoeings 30 and 50 DAS were administered for controlling weeds. Sevin® 50 WP (Carbaryl) at 1.750 kg ha^{-1} was sprayed at 50% flowering against pod borer complex. The second spray was done two weeks after the first spray during both the years. Rainfall received during the crop season was 797.4 mm in 1993 and 613 mm in 1994. In the first year, rainfall continued up to the end of September while in the second year it terminated on 15 September.

Phenological behavior of genotypes showed that AL 201 matured 11 to 13 days earlier than PPH 4 and about 17 days later than H 82-1. The behavior of flowering was almost the same during both years. AL 201 initiated flowering around 10 September, PPH 4 in mid-September and H 82-1 on 22 September. However, the maturity of the crop was considerably influenced by environmental conditions during the two years of study. In 1993, the maturity was delayed by a week as compared to 1994 as the total rainfall during the crop growth was not only high but also extended up to end of September in 1993, whereas in 1994 the rainfall occurred only up to mid-September.

During both years, hybrids PPH 4 recorded significantly higher grain yield than AL 201 (Table 1). In 1993, on an average, the differences due to plant density were significant. The spacings of 67.5 x 20 and 67.5 x 25 cm were statistically at par and produced significantly higher grain yields as compared to 30 x 15, 40 x 15, 60 x 15, and 67.5 x 30 cm spacings. The difference between 67.5 x 20 and 50 x 25 cm spacings were superior to AL 201 and H 82-1, yet varying plant densities did not differ significantly in the grain yield (Table 2).

Table 1. Effect of genotype and plant densities on the grain yield of pigeonpea grown at Ludhiana, India during rainy season 1993.

Genotype	Spacing (cm) 30 x 15	40 x 15	60 x 15	50 x 25	67.5 x 20	67.5 x 25	67.5 x 30	Mean
	Grain yield (kg ha^{-1})							
PPH 4	1540	1680	2110	2180	2700	2820	2380	2200
AL 201	1370	1710	1670	2050	1870	1840	1600	1730
Mean	1460	1700	1890	2120	2280	2330	2000	

	SEM	CV (%)
Genotypes (G)	31	13.8
Plant densities (P)	59	10.2
G x P	85	

Table 2. Effect of genotype and plant densities on the grain yield of pigoenpea grown at Ludhiana, India during rainy season 1994.

Genotype	Spacing (cm) 40 x 15	50 x 15	60 x 15	50 x 25	67.5 x 25	67.5 x 30	Mean
	Grain yield (kg ha^{-1})						
PPH 4	1900	2020	2360	2270	2450	2310	2220
AL 201	1870	1870	1820	1910	1670	1620	1790
H 82-1	1900	1940	1870	2010	1840	1700	1870
Mean	1890	1940	2020	2060	1990		1880

	SEM	CV (%)
Genotypes (G)	105	17.9
Plant densities (P)	87	8.6
G x P	93	

It was further revealed from Table 1 and 2 that the interaction between genotypes and plant density was significant during both the years. In 1993, hybrid PPH 4 produced highest grain yield at 67.5 x 25 cm spacing (6.0 plants m^2) while for AL 201 a spacing 50 x 25 cm (8.0 plants m^2) was found to be the best for obtaining maximum grain yield. Interestingly, the grain yield of hybrid PPH 4 reduced significantly when planted at closer spacings like 50 x 25 cm, 60 x 15, 50 x 15, 40 x 15, and 30 x 15 cm (Table 1). The decline in yield was also observed under the spacing of 67.5 x 30 cm. In 1994, PPH 4 gave maximum grain yield at 67.5 x 25 cm spacing, however, it was not significantly superior to 60 x 15, 50 x 25 and 67.5 x 30 cm spacings. A significant reduction in the grain yield was noticed when PPH 4 was planted at 40 x 15 and 50 x 15 cm spacings. This suggests that the hybrid needs to be planted further apart for higher yield.

Cultivars AL 201 and H 82-1 produced maximum grain yield at 50 x 25 cm spacing and the treatment was significantly better than 67.5 x 30 cm spacing.

The present study has clearly indicated that for PPH 4, the spacing of 67.5 x 25 cm was found to be the optimum while for cultivars AL 201 and H 82-1 the spacing of 50 x 25 cm was proved to be the best. In an earlier study, Saxena et al. (1992) also reported an increase in the grain yield of the hybrid ICPH 8, at wider spacings as compared to its parental varieties. The study has further

revealed a cut of 25% in seed rate of hybrid, which will ultimately minimize the cost of seed for raising a commercial crop.

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Evaluation of Vegetable Pigeonpea Lines in the Philippines

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In the Philippines, pigeonpea is called kardis or kadios. It is consumed chiefly as a vegetable whereby the tender green pods are among the vegetable components of an Ilocano recipe called "Pinakbet". Pinakbet recipe is a mixture of different vegetable fruits of eggplant, bittergourd, okra, bontoc pepper, tomatoes, and green pods of cowpea, lima beans, winged beans, yambeans, hyacinth bean, and also pigeonpea. Soft green seeds of pigeonpea are also mixed in meat dishes. The Ilocanos consider pigeonpea as a very good food item and the taste is comparable with other vegetable-legumes. Unlike other legume crops, traditionally, perennial pigeonpea is grown in limited areas like rice field bunds, backyards, and planted as hedgerows in sloping and hilly areas. After one season, the shrubs are ratooned for another season. The yield of dry grain is very low ranging from zero to 500 kg ha^{1}, which is very much lower than the yield in India which normally ranges from 400 to 700 kg ha^{-1} (DPR 1988). Considering the importance of pigeonpea, the Mariano Marcos State University (MMSU) in collaboration with the Cereals and Legumes Asia Network (CLAN) is undertaking a research and development program in pigeonpea. There is, therefore, a need to evaluate the genetic diversity of pigeonpea in relation to various farming systems in the Philippines.

An experiment was conducted at MMSU-Dingras during 1996-97 dry (Oct-Apr) cropping season. The study contained eight ICRISAT derived vegetable pigeonpea lines including the control, ICPL 87 (introduced in the Philippines in the early 1980s), to select the best lines for increased vegetable (green) production and to evaluate the potential of pigeonpea cultivation in Ilocos Norte, Philippines. The experiment was arranged in a randomized complete block design (RCBD) and replicated three times. Each entry was planted in 4-row plots of 5-m length and with an interrow distance of 60 cm. Two seeds were dibble-planted in furrows 20 cm apart and thinned-out to one plant per hill at one-and-half week after emergence. Optimum cultural requirements from planting to harvesting were followed to permit expression of genetic potential. Thirty kg N, 30 kg P_2O_5 and 30 kg K_2O per hectare were applied in the field at planting time. No irrigation was employed, thus, only the residual soil moisture was utilized by the plants. Spraying of the plants against pod borer with Decis 2.5 EC was done 50 days after planting (DAP) and 80 DAP. Harvesting of green pods was first done at 90 DAP with harvests at 7 days intervals until a fifth harvest, because the second flush of flowers occurred by then. The two inner rows were harvested for green pods and the two outer rows for seed production while other data gathered were taken from the two inner rows of each plot.

There were highly significant differences ($P<0.01$) in seed yield, 100 seed mass, pod size, and plant height among the genotypes evaluated under Ilocos Norte conditions (Table 1). The highest yield, both of green pods and of seed, was recorded from ICPL 93015 (8214 kg ha^{-1} and 2085 kg ha^{1}) but this was comparable to ICPL 87 (control variety). ICPL 93058 recorded the lowest yield of 4144 kg ha^{-1} (green) and 1000 kg ha^{-1} (dry). Bigger seeds were recorded in ICPL 93064 with 100 seed masses [36.6 g (green) and 15.0 g (dry)]. The control ICPL 87 had the smallest seeds [(24 g (green) and 9.3 g (dry)]. Genotype ICPL 87091 had the longest (9.73 cm) and broadest (1.47 cm) pod while the control ICPL 87 had the shortest (6.37 cm) and narrowest (0.90 cm) pod. Likewise, ICPL 93064 grew tallest (153 cm) while ICPL 87 was shortest (120 cm). All the genotypes tested except ICPL 87, flowered and matured at the same time (62 DAP and 130 DAP), respectively. ICPL 87 flowered 4 days and matured 6 days earlier.

Table 1. Performance of 8 1CRISAT vegetable pigeonpea genotypes grown at MMSU-Dingras, Ilocos Norte, Philippines, 1996/97.

Entry	Yield (kg ha^{-1})		100-seed mass (g)		Pod size (cm)		Plant height (cm)	Days to flower	Days to mature
	Green pods	Dry seeds	Green pods	Dry seeds	Length	Width			
ICPL 93015	8214	2085	32.0	13.6	8.77	1.40	145	62	130
ICPL 93020	5659	1211	30.9	13.7	9.50	1.43	134	62	130
ICPL 93058	4144	1000	31.6	13.8	9.46	1.37	131	62	130
ICPL 93064	6883	1489	36.6	15.0	8.77	1.40	153	62	130
ICPL 93066	5802	1249	31.9	13.9	8.97	1.53	130	62	130
ICPL 93070	5524	1170	32.8	14.1	8.83	1.30	142	62	130
ICPL 87091	5326	1116	32.2	13.9	9.73	1.47	126	62	130
ICPL 87 (control)	7631	1958	24.0	9.3	6.37	0.90	120	58	124
Mean	6148	1410	31.5	13.4	8.80	1.35	135	61	129
CV (%)	5.2	5.5	4.9	3.3	3.2	4.9	6.1		
SE	± 258.88	± 62.93	±1.26	±0.36	±0.23	±0.05	±6.71		

Because of the importance and demand for pigeonpea in the Ilocos, pigeonpea production should be encouraged especially in areas where only one cropping is practiced. Results showed that newly introduced genotypes can replace the traditional variety grown and therefore should be evaluated in farmers' fields before recommending such genotypes to the National Seed Industry Council (NSIC) for approval and release as varieties.

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Interspecific Hybridization Use of Detached Pistils in Studying Crossability Barriers and Treatment Effects in Pigeonpea

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In this study pigeonpea cultivar Pusa 33 and the wild species *Cajanus volubilis* were used. Seeds were sown in the month of June 1997 and crossability studies were done in March 1998 and March 1999.

Studies on pollen germination and pollen tube growth

Observations on pollen germination and pollen tube growth were done using Alexander staining method (1987). Two sources of pistils were used: (a) field pollinated pistils, which were collected from the field 2 or 3 days after pollination (DAP), (b) detached pistils where excised pistils (4-10 cross/treament) were pollinated and kept in humid chamber at 20.5°C for 48 h. The observations on pollen germination and pollen tube growth showed that both the pistils (treatment a and b) showed similar and consistent results and subsequently detached pistils were used to study crossability/treatment effects.

In control, the crosses *C. volubilis* x *C. cajan* var. Pusa 33 and its reciprocal pollen tubes growth was arrested in the stigmatic surface indicating pre-fertilization barrier. Different treatments such as bud pollination, stump pollination were tested and the results are presented in Table 1. The stigma and pollen were treated with n-hexane following Willing and Pryor (1976). In the cross *C. volubilis x C. cajan* var. Pusa 33, there was good pollen germination in stigmatic surface and pollen tubes entered into style. Due to poor stainability the pollen tubes could not be traced towards the ovary. The reciprocal cross also showed good germination but on stigmatic surface only. All the other treatments tested were not effective (Table 1).

Field pollination

In both the crosses, pollinated pistils dropped on 2 or 3 DAP. Twenty-five pigeonpea genotypes representing different maturity groups were used as pollen parents

Table 1. Observations on pollen germination and pollen tube growth in detached pistils after different treatments in the cross *C. volubilis* x *C. cajan* var. Pusa 33 (1) and its reciprocal (2).

Treatment	Cross	Pollen germination on stigma	Pollen tube entry into style
Control/bud pollination	1	+	–
	2	+++	–
Stump pollination	1	–	–
	2	–	–
Pollination on the stump + PGM	1	+	–
	2	+	–
Slit ovary wall + PGM	1	+	–
	2	+	–
Hexane washing of stigma + pollen	1	+++	√
	2	+++	–
Hexane washing of stigma & pollen + PGM on stigma	1	+++	√
	2	+++	–
0.5 M Nacl treatment of stigma	1	+	–
	2	+	–
Hot water treatment of stigma (55°C for 3min.)	1	+	–
	2	+++	–

+ Low,++ Medium, +++ High; PGM - Pollen germination medium. √ pollen tube entry into style, 5 pistils were observed/treatment after 48 h.

(80-100 pollinations/genotype) also produced the same results indicating the presence of strong prezyotic barrier in these crosses.

In March 1997, only 13 pistils could be pollinated after hexane treatment in the cross *C. volubilis* x *C. cajan* var. Pusa 33. Out of these 10 pods abscised on 9 DAP and each of the 3 remaining pod abscised at 14, 24, and 30 DAP respectively. Ten ovules obtained from these 3 pods in which heart shaped embryos were identified clearly.

In the next season (March 1998) the same treatment in the above cross produced 3 matured pods out of 185 pollinations attempted. Pod abscission started from 11 DAP, which indicate the presence of postzygotic barrier also. The bold seeds obtained from the 3 mature pods were germinated on small pots but due to infection the seeds and 3 seedlings of 8 days old were lost.

Pollination was also done after all the treatment as shown in the table except treatments 4 and 8. For each treatment 150-200 pollinations were done. In all these treatments pollinated pistils lasted for 2 or 3 days only.

The study showed two interesting results: (1) detached pistils technique can be helpful in testing large number of crosses or treatments with few flowers (5 cross/treatment) under regulated conditions before choosing a suitable one for large-scale field application. This also restricts aniline blue fluorescence method; (2) the hexane treatment was found to be effective in overcoming crossability barriers in the cross *C. volubilis* x C. *cajan* var. Pusa 33. The pod drop in this treatment can be overcome with some hormone treatments or embryo rescue technique.

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Ratoon Feasibility of Long-duration Pigeonpea Hybrids

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Commercial production of pigeonpea hybrid seeds is possible with the discovery of genetic male sterility coupled with its outcrossing nature. The genetic male sterility requires roguing 50% of the normal fertile plants from the female rows in the hybrid seed production blocks and the identification and collection of seeds from male sterile plants. The additional operation represents the primary additional expense involved in the production of hybrid seeds. In hybrid cultivation only F_1 seeds are used which need replacement every year. Two constraints— high price, and replacement of seeds—are the major bottlenecks in the popularization of hybrid pigeonpea cultivation among the Indian farming community. Pigeonpea has been characterized as a short lived perennial crop which can survive, under favorable conditions, for three to five years. Perenniality in pigeonpea is perhaps a remanant of its wild growth habit associated with its indeterminate nature. This characteristic is important in subsistence farming system where crop survival and stability of yield under

adverse conditions are important criteria. It is possible that this is further enhanced in the hybrids. In view of the above, an experiment was conducted to assess the seed yield performance of ratoon crop in long duration pigeonpea hybrids.

The main experiments were sown in the last week of July 1995/96 and 1996/97 with a view to take the ratoon crop. In the first year, 74 entries (71 hybrids + 3 controls) were sown followed by 38 entries (35 hybrids + 3 controls) in the second year. The material was supplied under the multilocational long duration hybrid test in a special project entitled "Promotion of Research and Development Efforts on Hybrids in Selected Crops, Pigeonpea". The experiments were conducted in RBD with two replications in both years in 4 m long plots two rows wide spaced at 75 x 30 cm. The main crop was harvested on 16 April 1996 and 1997 by cutting the fruiting zone with the help of scythe and the standing portion was left in the field for a ratoon crop. One irrigation was given by the flood method in the 3rd week of May to save the crop from hot summer in both the years. Owing to their deep root system and perennial nature about 80% of the plant population survived in the dry season and with the onset of monsoon quickly established a full canopy. In the first year a second cutting of 45 cm at the top, was done in order to control plant height on 8 August 1996.

The data recorded on yield in both main and ratoon crops are summarized in Table 1. The highest grain yield of 2314 kg ha^{-1} was recorded in the main crop by

Table 1. Comparative yield performance in main and ratoon crops of long duration pigeonpea hybrids at TCA Dholi, Bihar, India, 1995-97 and 1996-98 rainy season.

	1995-97					1996-98			
	Seed yield (kg ha^{-1})		Plant stand			Seed yield (kg ha^{-1})		Plant stand	
Hybrid	Main	Ratoon	Main	Ratoon	Hybrid	Main	Ratoon	Main	Ratoon
RAUPH 9001	1694	1413	16	9	RAUPH 9501	3240*	1300	18	8
RAUPH 9003	1441	710	20	10	RAUPH 9502	2649	600	20	5
RAUPH 9329	1773	1154	15	7	RAUPH 9503	2861	570	13	5
RAUPH 9410	1692	1094	17	10	RAUPH 9504	3592**	1135	25	6
RAUPH 9416	2167	948	18	9	RAUPH 9505	2583	425	23	7
RAUPH 9426	2300	815	19	11	RAUPH 9506	3731**	775	25	5
VPH 2019	1992	922	22	13	RAUPH 9507	3981**	1115	30*	6
VPH 2071	1562	1132	13	9	RAUPH 9508	3713**	1095	20	6
NDPH 94-1	1304	918	14	7	RAUPH 9509	2379	215	17	4
NDPH 94-6	1594	858	15	6	RAUPH 9515	3703**	973	14	7
NDPH 94-10	1645	705	17	10	RAUPH 9516	3917**	1210	15	6
NDPH 94-11	1847	1120	19	11	RAUPH 9518	3528**	1100	21	7
NDPH 94-13	1233	1165	19	11	RAUPH 9520	3806**	1115	17	9
NDPH 94-17	2049	908	22	11	RAUPH 9524	2796	345	12	4
NDPH 94-20	2314	963	25	12	RAUPH 9525	2824	290	18	6
Bahar (Control)	1973	1326	19	11	RAUPH 9527	3528**	976	22	8
					KPH 2083	2398	432	11	4
					KPH 2087	1537	565	22	8
					KPH 2088	2342	485	17	6
					NDPH 95-2	3546**	1065	15	7
					NDPH 95-5	3898**	1170	16	8
					Bahar (Control)	2601	1285	18	12
CV (%)	16.85	11.08	18.79	20.29		10.92	24.68	17.34	39.00
CD (kg ha^{-1}) 5%	453.60	168.00	5.11	3.00		517.30	310.00	9.72	3.87
CD (kg ha-') 1%	626.00	232.00	7.07	4.15		715.40	429.00	13.47	5.35

*Significant *at P = 0.05;* ** Significant at *P* = 0.01.

Table 2. Correlation between seed yield (kg ha^{-1}) and plant stand at harvest in main and ratoon crops of pigeonpea hybrids at TCA Dholi, Bihar, India, 1995-97 and 1996-98 rainy seasons.

	1995-97		1996-98	
Character	Main	Ratoon	Main	Ratoon
Seed yield (kg ha^{-1}) vs Plant stand at harvest	0.581[1]	-0.015	0.201	0.619[1]

1. Significant at P = 0.01.

the hybrid NDPH 94-20 while in the ratoon crop the highest yield of 1413 kg ha^{-1} was recorded by the hybrid RAUPH 9001. The control variety Bahar produced 1973 and 1326 kg ha^{-1} grain yield respectively, in main and ratoon crop. In the second year trial the highest yield of 3981 kg ha^{-1} was recorded by the hybrid RAUPH 9507 in the main crop while RAUPH 9501 recorded the highest grain yield of 1300 kg ha^{-1} in the ratoon crop. The minimum yield differences 970 kg ha^{-1} between main and ratoon crop was recorded by the hybrid KPH 2087. The control variety Bahar produced 2601 and 1285 kg ha^{-1} grain yield, in main and ratoon crop respectively during 1996-98. The hybrids RAUPH 9001 and 9501 had the same genetic background as MS 3783 x Bahar and showed superiority of grain yield in ratoon crop in both the years of experimentation. This suggests that the performance of hybrids in ratoon crop could be largely dependent on the genetic background of the parents involved.

Plant populations in both main and ratoon crops are summarized in Table 1. Thirty seeds were sown plot^{-1}, but the population was not uniform in both the years of experimentation. Very low plant population was recorded in all the treatments in ratoon crop, largely due to high mortality rate (about 20% plants died by the maturity of main crop). In the first year of the ratoon experiment the growth and plant population was very satisfactory as the plants developed luxurious canopy after receiving the first showers in the months of June-July. But there was high mortality after second cutting was done. This might be due to heavy rain just after cutting and water stagnation recorded up to 32 h in the experimental field. After removing the stagnated water serious mortality occurred in almost all the plots and 75% plants wilted within 2-3 days while in some plots 100% plant mortality was recorded. In the second year of trial the second cutting was not done. The ratoon crop developed full canopy and no plant mortality was recorded in the second year experiment till the start of flowering. In the month of December plants showed wilting symptoms after 15-20 days of flowering and as a result 100% plants had wilted by the end of February. In this experimental year, there was complete flower and pod abortion during December to second week of February due to extremely cold conditions.

The plant population was observed to be significantly associated with the seed yield in a ratoon crop (Table 2). Poor seed yield in a ratoon crop was due to unmanageable plant growth, high mortality, and poor pod setting. Plants of a ratoon crop bore pods at a greater height than the main crop which caused serious problems in agronomic and insect-pest management Although the number of primary and secondary branches were higher, the number of pod bearing clusters, pods cluster^{-1}, pods plant^{-1} and number of seeds pod^{-1} were very low in ratoon crop. These factors directly contributed to higher individual plant yield recorded in the main crop.

On the basis of these findings it is concluded that the raising of a ratoon crop in long duration pigeonpea hybrids in the northern part of India is not feasible. Due to high rainfall and excess soil moisture, plants attained 4-5 m height and suffered serious plant diseases such as phytophthora blight, sterility mosaic disease, and phyllody followed by wilting in the period of December to February during the reproductive phase.

Entomology

Insect Pest Incidence in Seed Pods of Pigeonpea Genotypes in On-farm Trials in Southern Malawi

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Pigeonpea (*Cajanus cajan* (L) Millsp.) is an important food and cash crop in Malawi. It is mostly grown in southern Malawi where it is consumed as green pea or dry grain, and exported as whole grain or *dhal* (Soko et al. 1994). Insect pests have been cited as one of the major biotic factors limiting pigeonpea production in Malawi (Reed 1987, Sithanantham and Reddy 1990). The economically important insect pest groups are the pod-sucking Hemiptera (dominated by *Clavigrella* spp.), pod-boring Lepidoptera (mainly *Helicoverpa armigera* Hubner, *Maruca vitrata* Geyer, and *Etiella zinckenella* Treitschke), and seed-boring Diptera (the pod fly, *Melanagromyza chalcosoma* Spencer).

Surveys conducted on farmers' fields in Malawi during 1995 and 1996 (Minja 1997) indicated that 15% of pigeonpea seed was damaged by insect pests. Pod-sucking bugs damaged 9.5% (60% of the total seed damage) of seeds in 1995 and 11.4% (75% of the total seed damage) of seeds in 1996. Pod borers damaged 6.0% and 3.6% of seeds, accounting for 38% and 24% of the total seed damage, respectively for the two seasons. Pod fly incidence was very low in both seasons, damaging <2% of seeds. The present studies were conducted in southern Malawi between July and September 1999 in a partnership between the Farming Systems Integrated Pest Management Project (FSIPMP), CABI Bioscience Global Project on legume pod borers and their natural enemies, and ICRISAT to enable farmers to evaluate the performance of improved high yielding medium- and long-duration pigeonpea genotypes in different cropping systems.

In 1999, pod-pest surveys were conducted within the Blantyre Shire Highlands Rural Development Project (RDP) Area, at on-farm trial sites in Nansadi and Mangunda sections of Matapwata Extension Planning Area (EPA) and Lirangwe section of Chiradzulu North (Mombezi) EPA. In this article only the results of the surveys in Mangunda section are reported, with brief comments from other parts of the RDP because trapping and trap security were most assured in Mangunda than in other sections.

The on-farm trials were designed by the FSIPM Project's agronomist and comprised of three main plots in each of the four farmers' fields. Two of the main plots had three sub-plots each planted with three long-duration genotypes (ICP 9145, ICEAP 00040, and ICEAP 00053). In one of the main plots, the pigeonpea was intercropped with maize. In the second main plot, pigeonpea was grown as a sole crop. In the third plot, four medium-duration genotypes (Chilinga, ICEAP 00068, ICEAP 00073, and ICP 6927) were grown on 4 subplots intercropped with maize.

At crop maturity, samples of 25 pigeonpea pods were randomly drawn from five plants in each subplot. The samples were examined in the laboratory for pest incidence and damage levels due to each pest group. Pods and seeds that were damaged by each pest group were expressed as proportions of the total number of pods/seeds per sample. In addition to pigeonpea, large numbers of pods from *Crotalaria ochroleuca*, *Tephrosia vogelii*, *Dolichos*, and other plant hosts were also collected and examined. Sampled borer larvae, pupae, or parasitoids were sorted out and reared for further identification.

Since pod and seed damage were expressed as proportions computed from numbers damaged by various pests, they were analyzed through logistic regression procedures (Collett 1991). All analyses were carried out taking into account the data structure as specified by the trial design, e.g., allowing for variation between farmers in all cases and nested data structure in the medium- and long-duration pigeonpea genotypes at Mangunda (Abeyasekera 2000).

The results are presented in terms of predicted percentages of seeds and/or pods showing damage. The results are also presented in the form of odds ratios, i.e.,

Table 1. Predicted % pod/seed damage and odds ratios of damage for medium-duration genotypes at Mangunda.

Genotype	Pods with external damage	Seed damage			Overall damage
		Borers	Sucking bugs	Pod fly	
Chilinga	7.0	2.0	39.0	0.4	41.4
ICEAP 00068	36.7	7.3	38.1	1.4	46.8
ICEAP 00073	14.0	2.3	45.0	1.2	48.5
ICP 6927	35.0	7.2	52.5	2.4	62.1
Sig. Prob.	<0.001	0.060	0.321	0.333	0.168
Odds ratios compared to Chilinga					
ICEAP 00068	7.79	3.80	0.96	3.34	1.25
ICEAP 00073	2.17	1.12	1.28	2.84	1.32
ICP 6927	7.22	3.73	1.74	6.11	2.30

the odds of damage to one genotype relative to the odds of damage to another genotype. The odds of damage for a particular genotype are defined as:

$$\frac{\text{Probability of damage}}{\text{Probability of no damage}} = \frac{\text{Probability of damage}}{1 - \text{Probability of damage}}$$

Two genotypes can be compared by looking at the ratio of their odds. For example, the odds of damage to ICP 6927 relative to Chilinga would be defined in terms of odds ratio as:

$$\frac{P_1/(1-P_1)}{P_2/(1-P_2)}$$

where P_1= probability of damage for ICP 6927 and P_2 = probability of damage for Chilinga.

The results from analysing the proportion of seeds/pods damaged among medium-duration genotypes indicate that pod-sucking bugs are a major problem for all genotypes (Table 1). There were some indications that Chilinga and ICEAP 00073 showed less damage to borers compared to ICEAP 00068 and ICP 6927. The odds of damage relative to Chilinga indicated that ICEAP 00068 had nearly 8 times higher odds of external damage to pods compared to Chilinga. The results on the long-duration genotypes showed that pod-sucking bugs are also a major constraint later in the season (Table 2). ICP 9145 showed less pest damage in intercrops compared to sole crops but the differences were not significant. With respect to overall damage and damage by pod-sucking bugs, the ICEAP genotypes showed slightly worse odds of damage compared to ICP 9145. The odds of damage were significantly different ($p<0.001$) between the locations, with higher values for the humid and cool sites (Matapwata) compared to the warm and semi-humid sites (Mombezi).

Determination of pod borers collected from different host plants revealed two species that were previously not identified although they are common on pigeonpea in the region. They have now been identified (by A. Polaszek, CABI) as a noctuid *Pardasena virgulana* that was occasionally parasitized by *Cotesia* sp., and a tortricid *Leguminivora ptychora*. *L. ptychora,* and *E. zinckenella* were also collected from *Tephrosia* pods. Within pods of both pigeonpea and *Crotalaria* a large species of chalcidoid wasp, *Eurytoma* sp. was abundant. *Eurytoma* species have varied biologies, being parasitoids, hyper-parasitoids, and herbivores. Parasitism of *Lampides boeticus* by *Neotypus intermedius* (Ichneumonidae) was high particularly on *Crotalaria; M. vitrata* parasitization by *Braunsia* sp. (Braconidae) was also greater on *Crotalaria* than on pigeonpea.

The predicted levels of damage by pod borer and pod fly are consistent with farmer field survey results for Malawi during 1995 and 1996 (Minja 1997). The predictions for damage by sucking bugs, however, seem to be much higher than the 4-17% levels that accounted for 70% of total seed damage in the previous surveys. The higher susceptibility of ICP 6927 to pest damage compared to other medium-duration genotypes had also been observed from trials in Kenya. Similar variations in damage by pod borers and pod fly on pigeonpea in different locations have been reported from other coun--tries in the region (Minja 1997). These variations are believed to be due to different levels of pest populations at different locations, possibly mediated by climatic and soil differences.

Given the evident seriousness of pigeonpea seed yield losses to pod pests in southern Malawi, immediate efforts should be made to assess the performance of elite pigeonpea genotypes against pod pests in different cropping systems

Table 2. Predicted % pod/seed damage and odds ratios of damage for long-duration genotypes at Mangunda.

Cropping pattern	Genotype	Pods with external damage	Seed damage		
			Borers	Sucking bugs	Overall damage
Intercrop	ICP 9145	12.8	5.3	37.6	42.9
	ICEAP 00040	20.0	7.1	48.9	56.0
	ICEAP 00053	32.8	10.8	44.5	55.3
	Sig. prob.	0.071	0.207	0.217	0.11
	Odds ratios compared to ICP 9145				
	ICEAP 00040	1.70	1.36	1.59	1.69
	ICEAP 00053	3.33	2.16	1.33	1.72
	ICP 9145	31.2	10.4	45.2	55.6
Sole crop	ICEAP 00040	15.2	5.1	53.5	58.6
	ICEAP 00053	25.6	9.4	54.4	63.8
	Sig. prob.	0.355	0.485	0.453	0.69
	Odds ratios compared to ICP 9145				
	ICEAP 00040	0.40	0.47	1.39	1.07
	ICEAP 00053	0.76	0.89	1.45	1.34
	Sig. prob. for cropping pattern	0.757	0.831	0.344	0.37

in other locations in the region. On-farm trials offer the best platform both to conduct such quantitative pest management assessments and to test any candidate pest management strategies.

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Efficacy of Different Insecticides for Pigeonpea Pest Management in Kenya

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The economically important insect pests of pigeonpea (*Cajanus cajan* (L.) Millsp.) in Kenya include the pod boring Lepidoptera (the most important are *Helicoverpa armigera* Hubner, *Maruca vitrata* (= *testulalis)* Geyer and *Etiella zinkenella* Treitschke, pod sucking bugs (dominated by *Clavigralla tomentosicollis* Stal and *C. horrida* Germar), and pod fly (*Melanagromyza chalcosoma* Spencer). Published information on pigeonpea insect pests as a constraint to production is limited in eastern Africa. In Tanzania, Materu (1970) reported that more than 50% of pigeonpea seeds were disfigured and unmarketable because of damage from pod sucking bugs. In Uganda, Kohler and Rachie (1971) recorded 5% seed damage by *H. armigera.* In Kenya, Okeyo-Owuor (1978) assessed losses in pigeonpea using data from pesticide trial and he attributed 13% seed loss to lepidopteran borers and 11% to pod fly. Surveys in farmers' fields in Kenya indicated that a number of farmers use pesticides for pest management on their traditionally grown land races (Minja et al. 1996). Among the insecticides commonly available to fanners in different locations in Kenya are: Permethrin (Ambush®), Deltamethrin (Decis®), Endosulfan (Thiodan®), Dimethoate (Rogor®), and Lambda-cyhalothrin (Karate®). However, there is little information on the type of chemicals that farmers should use on pigeonpea. To gather information on insecticide use on pigeonpea, trials were conducted at Kabete and Kiboko to evaluate the efficacy of some insecticides on short-, medium-, and long-duration pigeonpea genotypes.

At Kabete, six insecticides (Endosulfan [Thiodan® 35EC], Dimethoate [Rogor® E40], Pirimiphos-methyl [Actellic® 25EC], Tau-fluvalinate [Mavrik® 2E], *Bacillus thuringiensis* (Bt) [Thuricide® HP], and neem extract [Amrut Guard®]) were evaluated on the short-duration genotype ICPL 87091. At Kiboko, five insecticides (Endosulfan, Dimethoate, Pirimiphos-methyl, *B. thuringiensis* (Bt), and Deltamethrin [Decis ULV]) were evaluated on three pigeonpea genotypes (the short-duration ICPL 87091, medium-duration ICP 6927, and long-duration ICEAP 00020).

Pigeonpea was planted in the second week of November 1995 at Kiboko and Kabete in 20 m x 10 m plots, replicated thrice in randomized complete blocks. Four sprays of each insecticide were applied in each plot at 10-15 day interval starting at flower initiation. Endosulfan was applied at a rate of 1.0 kg active ingredient per hectare (a.i.ha^{-1}), Dimethoate at 0.5 kg a.i.ha^{-1}, Pirimiphos-methyl at 0.05 kg a.i.ha^{-1}, Tau-fluvalinate at 0.05 kg a.i.ha^{-1}, *B. thuringiensis* (Bt) at 0.4 kg a.i.ha^{-1}, and neem extract at 0.5 kg a.i.ha^{-1}. High volume spraying, i.e., 200 liters of water ha^{-1} was used throughout. Endosulfan and dimethoate were directly purchased from commercial stores, while pirimiphos-methyl, Bt, Deltamethrin, and neem were supplied by chemical company marketing offices.

Damage assessment was carried out at pod maturity (when most pods were mature but not dry). Pods from five randomly selected plants plot^{-1} were destructively sampled. Each pod was later examined for pod and seed damage and the insect pest that caused the damage. The number of seeds damaged by each pest group was expressed as a proportion of the total number of seeds plot^{-1} Grain yields were determined from each plot at harvest. Yield gains were calculated based on the differences between sprayed and unsprayed yields expressed as proportions of the unsprayed plot yields. Thus,

$$\text{Yield gain} = \frac{\text{Sprayed} - \text{Unsprayed}}{\text{Unsprayed}} \times 100$$

All data was subjected to analysis of variance using Genstat 5.

The major insect pests on pigeonpea were pod borers (*H. armigera, M. vitrata, E. zinkenella,* and *Lampides boeticus* L. at Kiboko; *H. armigera, E. zinkenella,* and *L. boeticus* at Kabete), pod sucking bugs (C. *tomentosicollis),* and pod fly (*M. chalcosoma)* at both locations. The results indicated that all sprays improved grain yields and seed quality at Kabete, with 57-152% grain yield gains in different insecticide treatments. Endosulfan appeared to perform better among the high volume sprayed insecticides at Kabete. Pod fly damage was less in plots treated with dimethoate than endosulfan (Table 1). Dimethoate has a depth action on plant surfaces which might have contributed to its effectiveness on pod fly larvae feeding inside the pods and egg laying adults.

Table 1. Seed damage (%) due to insect pests and grain yields of ICPL 87091 sprayed with different insecticides at Kabete, Kenya during 1995/96.

	Seed damage (%)				Grain yield and seed quality			
Treatment	Pod borers	Sucking bugs	Pod fly	Total	Yield (t ha^{-1})	Yield gain (%)	Damaged grain (%)	100-seed mass (g)
Endosulfan	6.1	6.6	2.8	15.5	2.50	152.5	1.0	14.3
Dimethoate	10.0	7.9	0.4	18.3	2.36	138.4	2.4	14.5
Pirimiphos-methyl	8.1	5.1	0.6	13.8	2.43	145.4	2.9	14.3
Tau-fluvalinate	11.5	9.6	0.8	21.9	2.20	122.2	1.0	14.8
B. thuringiensis	11.2	7.4	1.0	19.6	1.60	61.6	3.6	15.0
Neem extract	10.1	8.4	3.0	21.5	1.56	57.6	5.8	14.9
Untreated control	25.0	14.2	3.2	42.4	0.99	0	5.4	7.3
Mean	11.7	8.5	1.7	21.6	1.95	-	3.1	13.6
SE	±1.83	±1.15	±0.66	±1.18	±0.23	-	±0.65	±0.62
CV (%)	33.2	34.7	58.2	24.2	20.4	-	35.7	4.5

Table 2. Seed damage (%) due to insect pests on three pigeonpea genotypes sprayed with different insecticides at Kiboko, Kenya during 1995/96.

	Seed damage (%)										
	ICPL 87091[1]			ICP 6927				1CEAP 00020			
Treatment	Pod borers	Sucking bugs	Total	Pod borers	Sucking bugs	Pod fly	Total	Pod borers	Sucking bugs	Pod fly	Total
Endosulfan	0.2	0.8	1.0	1.7	3.0	0.3	5.0	0.3	3.8	2.8	6.9
Dimethoate	3.7	0.7	4.4	3.1	2.1	0.1	5.3	0.7	3.0	0.2	3.9
Pirimiphos-methyl	3.8	1.1	4.9	3.9	6.1	0.2	10.2	1.3	4.3	1.6	7.2
B. thuringiensis	9.8	1.1	11.0	3.0	3.6	0.4	7.0	1.5	9.9	2.4	13.8
Deltamethrin (ULV)	0.0	1.4	1.4	0.3	3.6	0.1	4.0	0.8	1.7	0.7	3.2
Mean	3.5	1.0	4.5	3.5	3.7	0.2	6.3	0.9	4.5	1.5	7.0
SE	±0.81	±0.56	±0.52	±0.81	±0.56	±0.12	±0.52	±0.81	±0.56	±0.12	±0.52
CV(%)	39.3	20.7	22.4	39.3	20.7	41.5	22.4	39.3	20.7	41.5	22.4

1. Pod fly incidence was negligible on ICPL 87091.

The results from Kiboko showed that the use of ultra-low-volume (ULV) spraying was most efficient in the management of the pests compared to the high volume sprayed insecticides. Endosulfan was also good among the high volume sprays (Table 2). Spraying the short-duration genotype with ULV resulted in lower pest population compared to the medium- and long-duration genotypes. The ULV spraying on the uniformly short crop ensured a better droplet cover than on the tall and spreading branches of the medium- and long-duration genotypes. ULV spraying may be of interest in the semi-arid pigeonpea growing areas where water is a limiting factor to high volume spraying. However, the cost/benefit and safety of using ULV have to be discussed carefully.

The results from Kiboko also showed that the incidence and damage due to pod sucking bugs and pod fly increased during the crop maturity phase. The populations of pod sucking bugs and pod fly increased gradually in the medium- to long-duration genotypes. Pod fly incidence on the short-duration pigeonpea genotype at Kiboko was negligible during the short rainy season. Pod borer incidence and damage, on the other hand, decreased during crop maturity phase. These insect pest population changes correlate to gradual decrease in temperature at Kiboko.

The seed losses reported by Okeyo-Owuor (1978) are much higher than in the present studies but they correlate well with results from farmers' field surveys in Kenya

(Minja et al. 1996). It was further observed in farmers' fields and at research stations that insect pest populations on pigeonpea vary greatly between locations and between seasons at the same location. Different pigeonpea genotypes were also used at Kabete and Kiboko where crop management was different from that on farmers' fields.

The results on insecticides indicated that neem extract and *B. thuringiensis* were not as effective as the synthetic insecticides in reducing pest numbers and pigeonpea seed losses at Kabete and Kiboko. Neem extract and *B. thuringiensis* are among the commonly used biopesticides. They act slowly and have to be ingested, and are, therefore, suitable for some of the pod borers (e.g. *H. armigera),* where treatments should start very early in the season. If farmers adopt biopesticides, they have to be prepared for higher crop losses than when they would use conventional chemical pesticides. The advantage of biopesticides is that they are safer than chemical pesticides. Substantial numbers of general predatory arthropods were observed at Kabete and Kiboko during the vegetative and reproductive stages of the crop. These arthropods are easily killed by some of the non-selective insecticides. Among the conventional insecticides, endosulfan is known to be selective against some of the natural enemies of insect pests (Wiktelius et al. 1999).

Judicious use of these pesticides has to be adopted to safeguard the environment and health of farmers and consumers (Holt et al. 1990). This is important because there are reports of H. *armigera* resistance to pyrethroids and endosulfan in India (Lateef 1991). It is advisable to alternate chemical pesticides at least between seasons but more reasonably between two or three sprays within a season to minimize the tendency of pests developing resistance to a particular chemical. It is of practical importance to scout fields to assess pest incidences. This will assist in making decisions that will minimize environmental contamination through unnecessary use of pesticides. Thus there is need for thorough training of farmers before they embark on wide use of pesticides on pigeonpea in the region.

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Insect Pest Incidence on Long-duration Uganda Pigeonpea Lines at Kabete in Kenya

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Pigeonpea (*Cajanus cajan* (L.) Millsp.) is an important food legume that is both consumed and traded in the local markets in northern Uganda and across the border in southern Sudan. Germplasm collection has not been made and improved varieties have not been disseminated widely in northern Uganda partly due to civil strife in the main pigeonpea growing areas in Gulu, Kitgum, and Moyo. Efforts were made by staff of the Pigeonpea Improvement Project for Eastern and Southern Africa in 1998 to visit a few farmers in Kitgum and Gulu and collect seed samples of the long-duration local landraces. The visit capitalized on the peaceful period that has been prevailing in the area for the past two years.

The common and widespread insect pests on pigeonpea in Kenya and Uganda include the pod-boring Lepidoptera *(Helicoverpa armigera* Hubner, *Etiella zinkenella* Trcitschkc, *Maruca vitrata [= testulalis]* Geyer, and *Lampides* sp.), pod-sucking bugs (dominated by *Clavigralla tomentosicollis* Stal), and seed-feeding Diptera (*Melanagromyza chalcosoma* Spencer) (Minja et al. 1996, Night and Ogenga-Latigo 1994). Most of the available information was gathered from surveys conducted in farmers' fields on traditionally grown medium-duration landraces in Lira and Apac districts.

Seed from eight local long-duration landraces were collected from farmers' fields in Kitgum and Gulu in September 1998. The seed was planted in the second week of November 1998 at Kabete in Kenya. Plots consisted of two rows of 10 m at a spacing of 1.5 m x 1.0 m. The plots were constantly weeded by hand and the plants were not sprayed.

Insect pest incidence and damage assessments were carried out at pod maturity in September/October 1999. Three samples of 50 pods each were randomly drawn from the middle of each plot leaving a 2-m border at row edges. Each pod was examined for pod and seed damage and the insect pest that caused the damage. The number of seeds damaged by each pest group was expressed as a proportion of the total number of seeds plot^{-1}.

The insect pests that caused damage on the pigeonpea lines were pod fly (*M. chalcosoma*), pod borers (*E. zinkenella, Lampides* sp., and *H. armigera*), and pod sucking bugs (C. *tomentosicollis*). In general total seed damage was low and the percentage damage by pod fly ranged from 2-7%. Pod fly accounted for 80% of the total seed damage on the lines, pod borers 12.7% and pod-sucking bugs 6.3% (Table 1). ICEAPs 00954, 00955, 00956, and 00957 had relatively higher levels of damage and could be described as more susceptible than the other lines. ICEAP 00953 and 00958 appeared to be more tolerant to pod fly. ICEAP 00955 has slightly larger seeds and less number of pods compared to other lines, and the seed coat is brown. The other lines set more pods and have speckled cream seed coats. Observations from multilocation trials in Kenya and Tanzania indicated that when cream seeded genotypes from low to medium altitude were grown in high altitude locations such as Kabete [1825 m above sea level (a.s.l.)], their

Table 1. Pod and seed damage (%) due to insect pests on Uganda pigeonpea lines at Kabete, in Kenya during 1998/99.

Line No.	Total seed in sample	Pod damage due to borers (%)	Pod borers	Seed damage (%)		
				Sucking bugs	Pod fly	Total
ICEAP 00953	164	0.0	0.2	0.2	2.3	2.7
ICEAP 00954	166	5.7	1.7	0.2	6.4	8.3
ICEAP 00955	163	2.7	1.2	0.2	6.8	8.2
ICEAP 00956	110	6.8	2.2	0.0	5.8	8.0
ICEAP 00957	148	1.9	0.7	1.6	7.0	9.3
ICEAP 00958	153	1.0	0.4	0.0	2.0	2.4
ICEAP 00959	135	0.0	0.0	0.5	5.1	5.6
ICEAP 00960	205	0.0	0.0	0.6	5.1	5.7
Mean	156	2.3	0.8	0.4	5.1	6.3
SEM	6.97	1.53	0.43	0.41	1.40	1.90
LSD (0.05)	21.14	4.64	1.30	1.24	4.25	5.76

seed turned brown. The original seed from Uganda was cream. Eight lines have been planted at Kiboko (940 m a.s.l.) where the temperatures are higher than Kabete and the seeds are therefore expected to have cream color.

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Natural Enemies of Pod Borers in Pigeonpea

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Natural enemies of *Helicoverpa armigera* have been reported by several workers in the past (Bhatnagar 1981, Pawar and Jadhav 1983, and Reed et al. 1989). Published information on the predation of the larvae of *Maruca vitrata, Nanaguna breviuscula,* and *Grapholita critica* is very scanty. The parasitization of *G. critica* by *Apanteles taragamae* has been reported earlier by Paramanik and Basu (1968) from West Bengal and by Lateef and Reddy (1984) from Andhra Pradesh, but there is no earlier record of this parasitoid on *M. vitrata.* Similarly, information on parasitization of *N. breviuscula* is not available in literature. This paper reports the natural enemies of pod borers in pigeonpea in Bhubaneswar, Orissa.

During the rainy season of 1994 and 1995 the occurrence of both nymphs and/or adults of mud wasps, spiders and praying mantis was recorded in 12 randomly selected plants at 0800 h and at 1700 h at weekly intervals commencing from the vegetative stages of the crop. The extent and period of parasitization of *N. breviuscula, M. vitrata,* and *G. critica* were studied in the laboratory at the Department of Entomology, Orissa University of Agriculture and Technology. Fifty late-instar (4th- to 6th-instar) larvae of each borer species were collected randomly from the pigeonpea fields at weekly intervals and were reared individually in specimen tubes (10 x 2.5 cm). Fresh plant buds, flowers, and pods were provided daily to the larvae till pupation or mortality due to parasitization. The extent and period of parasitization were computed for each parasitoid species. The parasitoid species were identified by Dr T C Narendran, Professor, Department of Zoology, University of Calicut, Kerala.

The activities of the predators such as spiders, praying mantis, and wasps (Fig. 1) were observed between mid-August and mid-December (33rd to 50th week) and their numbers ranged from 0.1 to 3.5, 0.0 to 1.2, and 0.0 to 0.9 plant^{-1} respectively (Table 1). Maximum abundance of the predators was recorded during the last week of September (39th week) which coincided with high population of the pod borers during flowering to pod elongation stage. The spiders, praying mantis, and hymenopterous wasps (*DeIta conoideum* Gmelin *D. campaniforme esuriens* Fab, and *D. pyriforme* Fab.) predated on the larvae of *M. vitrata, N. breviuscula, G. critica,* and *H. armigera.* The predation of H. *armigera* by these predators confirmed the observations by Bhatnagar (1981), Pawar and Jadhav (1983) and Reed et al. (1989).

The braconid *A. taragamae* (Fig. 2) parasitized the larvae of *M. vitrata* and *G. critica* (2.0% to 7.0% and 2.0% and 2.0% to 9.0% respectively) during mid-September (37th week) to late-December (52nd week) (Table 2). Maximum parasitization of *M. vitrata* (7.0%) was recorded in mid-November (46th week) and that on *G. critica* (9.0%) during September (39th week). On an average, the extent of parasitization of *M. vitrata* was 4.7 ± 2.0% and that of *G. critica* 3.8 ± 2.8%.

Table 1. Predators of pigeonpea pod borers.

Predators	Crop season	Period of occurrence (std. wk)	Population (plant^{-1}) Range	Mean ± SD
Spiders	1994-95	33-46	0.1-4.1	1.9 ± 1.4
	1995-96	34-50	0.0-3.2	1.5 ± 1.5
Mean		33-50 (39)[1]	0.1-3.5	1.5 ± 1.1
Praying mantis	1994-95	37-46	0.1-1.3	0.6 ± 0.4
	1995-96	38-50	0.0-1.9	0.6 ± 0.6
Mean		37-50 (39)[1]	0.0-1.2	0.5 ± 0.4
Wasps	1994-95	38-45	0.0-1.0	0.4 ± 0.4
	1995-96	38-48	0.0-0.9	0.4 ± 0.4
Mean		33-48 (39)	0.0-0.9	0.4 ± 0.3

1. Indicates peak period of activity.

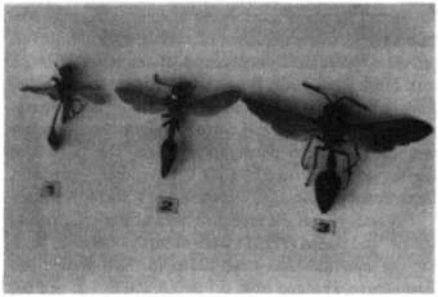

Figure 1. (A) *Delta campaniforme esuriens* Fab.; (B) *D. conoideum* Gmelin; (C) *D. pyriforme* Fab.

Figure 2. *Apanteles taragamae* Viereck.

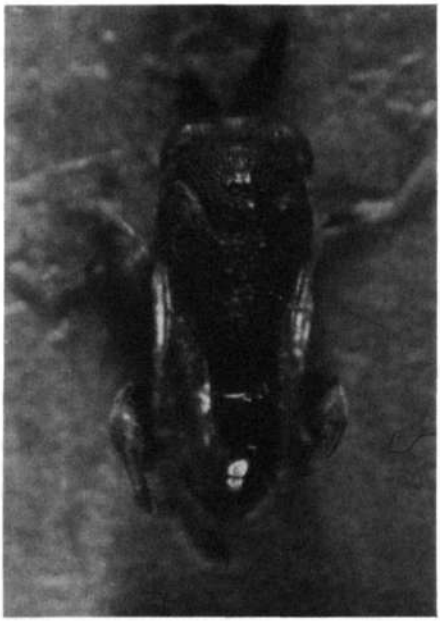

Figure 3. *Brachymeria atteviae* Joseph, Narendran & Joy.

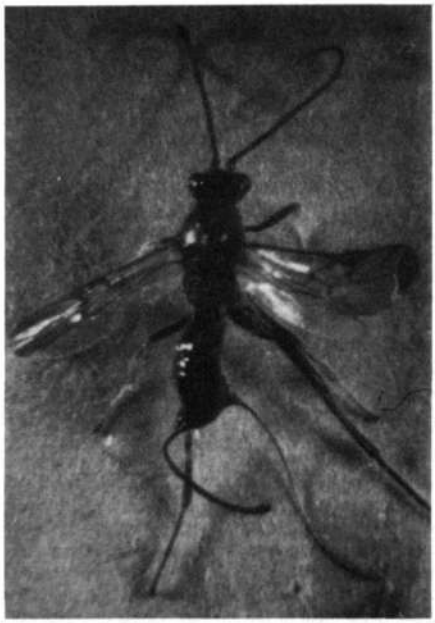

Figure 4. *Microdes* sp.

Table 2. Parasitoids of pigeonpea pod borers.

Parasitoid	Host	Crop season	Period of occurrence (std. wk.)	Extent of parasitization (%)	
				Range	Mean ± SD
Apanteles taragamae (Viereck)	*M. vitrata*	1994-95	39-50	2.0-8.0	3.7 ± 2.3
(Braconidae: Hymenoptera)		1995-96	39-52	0.0-12.0	6.3 ± 4.4
Mean			39-52 (46)[1]	2.0-7.0	4.7 ± 2.0
	G. critica	1994-95	37-46	0.0-8.0	3.6 ± 3.0
		1995-96	39-50	0.0-10.0	5.3 ± 3.7
Mean			37-50 (39)[1]	2.0-9.0	3.8 ± 2.8
Brachymeria atteviae	*N. breviuscula*	1994-95	44-50	2.0-10.0	6.0 ± 3.7
(Joseph, Narendran, and Joy)					
(Chalcididae: Hymenoptera)		1995-96	44-52	2.0-14.0	8.0 ± 5.1
Mean			44-52 (47)[1]	1.0-12.0	6.4 ± 4.6
Microdes sp.	*M. vitrata*	1994-95	39-50	2.0-12.0	6.0 ± 4.0
(Braconidae: Hymenoptera)		1995-96	44-52	2.0-12.0	6.8 ± 4.8
Mean			39-52 (46)[1]	1.0-12.0	5.0 ± 4.5

1. Figures in parentheses indicates peak period of activity.

The activity of the chalcidid larval-pupal parasitoid, Brachymeria attevae Joseph, and Narendran and Joy (Fig. 3) was first observed in early-November (44th week) coinciding with the maximum population of *N. breviuscula* (16.4 larvae plant^{-1}). The extent of parasitization ranged between 1% and 12% with an average of 6.4 ± 4.6%. The parasitoid activity continued up to late-December (52nd week) with the maximum parasitization (12.0%) in the 47th week.

Microdes sp. a larval-pupal braconid parasitoid (Fig. 4) parasitized *M. vitrata* from late-September (39th week) to late-December (52nd week) (1-12% parasitization). Maximum parasitization (12.0%) was recorded during mid-November (46th week). Extent of parasiziation of *M. vitrata* was 5.0 ± 4.5% (Table 2).

The parasitization by B. *atteviae* on *N. breviuscula* and *Microdes* sp. on *M. vitrata* are the first records of their kind from Orissa.

Acknowledgment. The authors wish to thank Dr T C Narendran, Professor, Department of Zoology, University of Calicut, Kerala for helping in identification of parasidoids.

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Seasonal Incidence of New Pigeonpea Pod Borer Species, *Nanaguna breviuscula* Walker on Genotypes of Pigeonpea

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Nanaguna breviuscula Walker, a pod damaging pest of pigeonpea was first reported from Orissa by Samalo and Patnaik (1984), while Sahoo and Senapati (1993) reported its occurrence in southeastern Orissa. However, no published information is available on its seasonal occurrence and incidence in Orissa or other pigeonpea growing areas of the world.

Three varieties, UPAS 120 (short duration), C 11 (medium duration), and PUSA 9 (long duration) were sown in strips of 20 m^2 under rainfed conditions in sandy-loam soil (pH 6.9) during the first week of July 1994 and 1995. The observations on Nanaguna larvae were recorded at weekly intervals on 12 tagged plants at random from 31st standard week (30th July to 5th August) in the morning hours.

Nanaguna breviuscula infestation started in the 40th standard weeKs (continued up to 45th week) during 1994 and 42nd standard week (continued up to 46th week) during 1995 (Fig. 1). The peak larval population was recorded in the 45th standard week (early November) in both the years and high larval density (7.5-16.4 plant^{-1}) was recorded during the first fortnight of November.

Medium duration variety was infested in second fortnight of November (47th or 48th standard week) coinciding with the flowering stage of the crop and continued up to the end of December (52nd standard week). The maximum larval activity was recorded in late-November to early-December (26 November-9 December) which coincided with the flowering stage of the crop. Insect density was greater in 1995 than in 1994.

The larvae appeared on the late-duration variety (PUSA 9) in the first fortnight of December (49th or 50th standard week) at bud initiation stage of the crop and the infestation continued up to 3rd and 1st week of January of 1995 and 1996 respectively. The highest larval population was recorded either in the 50th (1994 crop) or 49th (1995 crop) standard week which coincided with 50% flowering stage of the crop.

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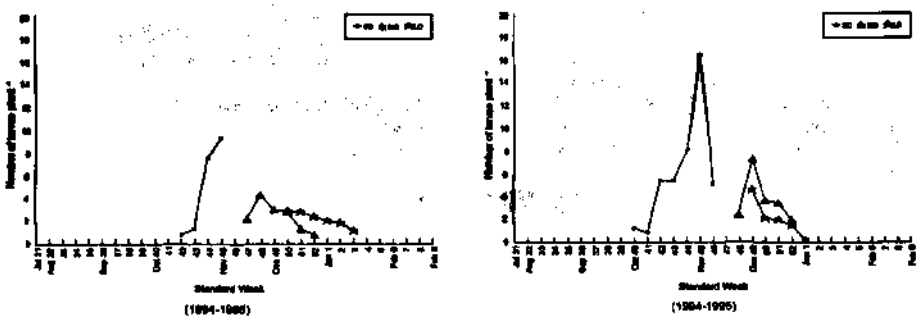

Figure 1. Seasonal incidence of *N. breviuscula* Walker on pigeonpea genotypes during 1994-95 and 1995-96 at Bhubaneswar, Orissa, India.

Paras: An Early Maturing Pigeonpea in the Arhar-Wheat Rotation

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Pigeonpea research work at Hisar was initiated in early 70s with the major objective of developing early maturing varieties and formulating a package of practices for their successful cultivation. Initially, evaluation of germplasm and varieties developed elsewhere, resulted in identification and release of three early maturing varieties-UPAS 120, Prabhat, and T 21. With these varieties, pigeonpea cultivation gained momentum in the state. These varieties fit fairly well in pigeonpea-wheat rotation. This newly introduced crop attracted the farmers by virtue of good returns in terms of grains and sticks for fuel with only little expenses on inputs.

Considering the popularity of pigeonpea among the farmers and increasing upward trend in its area (under cultivation) and production, the research work was further intensified and hybridization program initiated. Single, three-way and double crosses were made to create genetic variability. The breeding material was handled through pedigree, bulk, and single seed descent methods. The concerted efforts of the research scientists yielded fruitful results in terms of development and release of early maturing variety "MANAK" at national level (NWPZ). This variety further increased the area under pigeonpea crop in Haryana due to its superiority over UPAS 120.

Figure 1. Crop view of Paras.

Another significant achievement is the development and release of one more early maturing variety, Paras, for general cultivation in Haryana. This variety was identified as promising, both at state and national level.

The variety Paras was developed from the cross EE-76 x UPAS 120 following pedigree selection method. This variety does not differ much from Manak and UPAS 120 in its plant architecture, but has substantially more number of pod bearing branches and pods while seed mass is marginally higher than the controls (Table 1). It also contains higher protein (20.34%) than Manak (19.25%). This variety is suitable for normal sown conditions and also performs well under late sowings because of its remarkable early vigor. At present, late sowing appears to be the best approach to attain agronomic dwarfism.

Paras (H 82-1) was tested extensively in various trials such as station trials, coordinated trials, late sown trials,

Table 1. Characteristics of Paras, Manak, and UPAS 120 as per field evaluation at Hisar.

		Controls	
Characters	Paras	Manak	UPAS 120
Days to 50% flowering	69	72	75
Days to maturity	145	140	144
Plant height (cm)	219	211	213
Pods per plant	149	124	105
Fruiting branch per plant	12.0	10.2	9.1
100 seed mass (g)	7.8	7.5	7.3
Protein (%)	20.34	19.25	21.44
Seed color	Light brown	Light brown	Brown

Table 2. Summary of seed yield (kg ha^{-1}) of Paras (H 82-1) and controls over years and locations.

Trials	Paras (H 82-1)	Controls				
		UPAS 120	Pusa 33	Manak	ICPL 151	Prabhat
Coordinated trials in NWPZ (3 years)	1909(24)	1717(22)	1720(22)	1794(24)	1720(10)	–
Station trials over 6 years (timely sown)						
14 trials	2181	1902	–	2024	–	–
23 trials	1975	–	–	1788	–	–
Station trials in Haryana (late sown)						
Seven trials in 7 years	1557	–	–	1314	–	1178
Three trials	1759	1294	–	1424	–	1240
Agronomical trials (3 trials in Haryana)	1411	–	–	1380	–	–
Farmers' field trials (27 trials in two years)	1713	–	–	1465	–	–

Figures in parentheses are number of locations.

agronomic trials, and farmers' field trials and out-yielded the controls and ranked first in coordinated trials. Overall increase in yield over Pusa 33 was 11% and UPAS 120 was 11.2% (Table 2). In most cases, the yield of Paras was significantly higher than the control.

The perusal of the date in table 2 clearly indicated the superiority of the new variety, Paras (H 82-1), in all the trials. Presently, mere are no serious problems of pigeonpea diseases in Haryana, possibly due to the limited area under cultivation. Nevertheless, its (Paras) reaction to major disease was observed and it was found that the disease reaction of Paras was at par with Manak. However, infestation of pod borer in Paras was 26% as compared to 25% in Manak, and 20% in UPAS 120. Incidence of pod fly in Paras was 15%, Manak was 20%, and UPAS 120 was 26%.

Thus, considering its clear superiority over control varieties, Paras has been officially released and notified for general cultivation in Haryana. It was notified by Central Government vide S.O. 401 (E) dated 15 May 1998 and circulated circular No. 5455-73 dated 21 July 1998. Once, its high quality certified seed is made available to the farmers, it is expected that the area and production of pigeonpea will increase in Haryana and adjoining states.

The variety, Paras, is presently being used as national control in the All India Coordinated Varietal trials of early pigeonpea.

SKFA 3, A Dwarf, Short-duration, High-yielding Pigeonpea Variety for Double Cropping

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Predominantly in India, medium to long-duration pigeonpea varieties/landraces are culvitated as intercrop with cereals or cotton. Since pigeonpea takes 6-9 months to mature, the crop does not find place in prime lands and is generally pushed into marginal and semi-marginal rainfed lands. The crop also receives little attention from cultivators. All these factors result in low yield but the demand and returns encourage the farmers to grow pigeonpea. One of the ways to increase its production is the introduction of short-duration pigeonpea varieties in prime lands which will permit crop rotations.

To develop high yielding short-duration pigeonpea varieties suitable for double cropping in Madhya Pradesh and Rajasthan, ICPL 85091, ICPL 88009, and ICPL 84031 were introduced from ICRISAT in 1995. These were evaluated at Sipani Krishi Anusandhan Farm (SKAF), Mandsaur. Among these, ICPL 84031 looked very attractive and a number of high-yielding single plants were selected to develop a suitable variety for the region.

Figure 1. View of SKFA 3 crop.

Table 1. Yield (t ha^{-1}) of SKAF 3 and control cultivar at SKA farm, Mandsaur, Madhya Pradesh, India.

Variety	1997/98	1998/99	Mean
SKFA 3	2.18	2.38	2.28
ICPL 84031	1.24	1.32	1.28
K 7 (Control)	1.07	1.19	1.13
SE	±0.09	±0.04	
CD (P = 0.05)	0.25	0.11	

From the single plant progenies, grown in 1996, SKFA 3 was found very promising. At Mandsaur this line was evaluated along with parental population ICPL 84031, and K 7 as local control. During 1997/98 and 1998/99 seasons, these lines along with eight other entries were evaluated in randomized block design with 4 replications in 10 m^2 plots. In both the years, sowing was done in the first week of July with intrarow spacing of 25 cm and interrow distance of 10 cm. A basal fertilizer dose of 40:60:40 NPK ha^{-1} was used. Seeds were sown at a depth of 2-3 cm. The crop was protected from pod borers by 5 insecticidal sprays starting from 30 days after sowing. Harvesting was done at 90% pod maturity. Over two seasons, SKFA 3 (2.28 t ha^1) outyielded ICPL 84031 (1.28 t ha^{-1}) by margin of 78% and control K 7 (1.13 t ha^{-1}) by 102% (Table 1).

SKFA 3 is a short-duration (128 ± 2.5 days) variety which flowers in 65 ± 2.4 days (Fig. 1). It grows up to 150 ± 4.0 cm in height. The plants are determinate in growth habit. Its pods are green with brown stripes and on average each pod contain 4.5 ± 0.3 orange colored seeds. Seeds of SKFA 3 contain 21.2% protein and 100-seed mass of 8.4 g.

The crop matures by October-end which provides sufficient time for field preparations and sowing postrainy season crop like wheat or chickpea. In Madhya Pradesh SKFA 3 can substitute other rainy season crops like soybean and maize. Since pigeonpea commands high price, it is visualized as the future crop of the region.

Acknowledgment. Authors greatly acknowledge ICRISAT for supplying seed of ICPL 84031 from which SKAF 3 was derived through single plant selection.

Multifoliate Variants in Pigeonpea

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Pigeonpea (*Cajanus cajan* (L.) Millsp.) plant has pinnately compound trifoliate leaves but sometimes a natural variation in the leaf morphology and number of leaflets is observed (Reddy 1990). A plant progeny with multifoliate leaves was identified during the rainy season of 1999 in the breeding material TT44-4, derived from an inter-specific cross of TT5 (a radiation induced mutant cultivar T21 of *Cajanus cajan)* and *C. scarabaeoides.* All the 18 plants of this progeny had 3,4, 5, or 6 leaflets per leaf. A few leaves with 7 and 8-leaflets were also observed at maturity (Fig. 1). Data on the number of leaflets per leaf, the frequency of their distribution within the plant and other parameters were scored at 35 days after sowing. At this stage, all the leaves including primary leaves were intact on the plants.

In the multifoliate plants, the total number of leaves, estimated as the mean of 10 plants, was less (16 ± 1) than the normal (control) trifoliate plant (20.6 ± 1.4).

Figure 1. Multifoliate leaves of pigeonpea.

However, the total number of leaflets per plant between the normal trifoliate (61.8 ± 4.1) and multifoliate (63.7 ±4.0) variant plants was similar. This indicates that the presence of additional leaflets resulted in the reduction of total leaf number. The proportion of the leaves with 3, 4, and 5 leaflets in the multifoliate plants was found to be more or less similar, i.e. 33.8 ± 4.2, 33.8 ±5.1, and 30.0 ±3.3% respectively. The proportion of the hexafoliates was low (1.9 ± 1.3%).

In an interspecific cross of pigeonpea, Reddy (1990) reported the occurrence of tetra to hexafoliates along with normal trifoliates. In addition to this, a report on the variants with 5-7 leaflets per leaf has also been cited (Sengupta et al. 1986). The occurrence of 8 leaflets per leaf with low frequency has been observed in this study for the first time (Fig. 1). The factors responsible for such variation are not known. Interaction between genes and cytoplasm of the two *Cajanus* species or spontaneous mutation could be a possibility.

Studies on penetrance and expressivity, inheritance and yield parameters of the multifoliate trait are planned.

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Performance of ICRISAT Pigeonpea Varieties on Smallholder Farms in Southern Malawi

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Pigeonpea is widely grown in southern Malawi as an intercrop with maize. It is a valuable food source for resource-poor farming households and is now also recognized as being an important cash crop. The crop however often suffers yield losses due to *Fusarium udum* and other diseases. The use of resistant cultivars offers the only viable technology for management of *Fusarium*.

The Farming Systems Integrated Pest Management (FSIPM) Project evaluated three long duration pigeonpea cultivars for their performance against *Fusarium* wilt in researcher-designed, farmer-managed on-farm trials during two crop seasons from 1997 to 1999, in the Blantyre Shire Highlands Rural Development Project area of Blantyre Agricultural Development Division in southern Malawi. The FSIPM Project was aimed at providing small-scale resource-poor farmers with acceptable and sustainable integrated pest management strategies that reduce crop losses by pests and diseases. This article summarises the findings from these trials and discusses the suitability of these varieties for farmers in Blantyre Shire Highlands.

The genotypes selected for the trials were the Kenyan landraces ICEAP 00040 and ICEAP 00053, which are being promoted regionally because of their high yield potential and large seed size. ICEAP 00040 is wilt-resistant whereas ICEAP 00053 is only regarded as wilt-tolerant. The performance of these lines under smallholder management in Malawi was evaluated in Chiradzulu North (Mombezi) and Matapwata Extension Planning Areas (EPAs) with farmers whose fields were situated in either dambo or upland land types. As a control, the local pigeonpea variety was included in the trials along with the wilt-resistant variety ICP 9145, first released in Malawi in 1987 (Makato 1997).

Sixty-one farmers participated in the 1997/98 trial and 40 in the 1998/99 trial. All four varieties, one plot per variety, were grown on each farm so that farmers could observe varietal differences. The experimental design, detailed in Abeyasekera (1999), was that of an incomplete, randomized block experiment with farmers regarded as blocks. The design took account of additional pest management strategies applied to the intercrops (maize, pigeonpea, and beans). Yield data was analyzed using Genstat 5 Release 4.1 using general linear modelling techniques suitable for dealing with unbalanced data. Modelled results are reported here, adjusted for other sources of variation. Proportions of plant deaths were analyzed using logistic regression procedures (Collett 1991).

The results from analysing usable seed mass (net yield after removal of damaged seed) showed clear differences between varieties and across EPAs and land types (Fig. 1 and 2). It is evident that all varieties performed better in the second season, while the best performance consistently occurred in the drier and warmer upland

Table 1. Plant mortality (%) due to *Fusarium* wilt.

Season	Variety	Chiradzulu		Matapwata		Overall
		Dambo	Upland	Dambo	Upland	
1997/98	Local	7.3	5.3	52.0	39.5	24.4
	ICEAP 00053	7.5	6.5	53.1	44.9	25.3
	ICEAP 00040	5.4	4.8	44 1	36.9	21.3
	ICP 9145	3.9	4.3	36.3	32.8	18.1
1998/99	Local	7.1	9.2	2.9	3.3	6.1
	ICEAP 00053	6.4	8.2	8.4	9.2	7.9
	ICEAP 00040	2.5	3.0	3.0	3.3	2.9
	ICP 9145	3.3	4.1	1.9	2.2	3.1

fields in Chiradzulu North EPA. In 1997/98, ICEAP 00040 and ICP 9145 produced higher yields than the local variety or ICEAP 00053. Variety differences were more marked in dambo fields ($p < 0.001$) than in the uplands ($p = 0.014$). In upland fields ICEAP 00053 performed worst, giving significantly lower yields than ICEAP 00040 ($p = 0.003$) and ICP 9145 ($p = 0.054$). In the 1998/99 season, ICEAP 00053 performed better, but its yield was not significantly different from that of the other varieties. ICEAP 00040 performed significantly better than either the local variety or ICP 9145 in this season.

Varieties also differed significantly in both seasons with respect to *Fusarium* wilt incidence (Table 1). ICEAP 00040 and ICP 9145 consistently had significantly lower mortality ($p < 0.001$) than ICEAP 00053 or the local variety. There was little evidence of a difference between ICEAP 00040 and ICP 9145 ($p = 0.061$ in 1997/98 and $p = 0.081$ in 1998/99). In the first season, damage levels due to *Fusarium* were very high in Matapwata EPA and here the benefit of ICP 9145 in particular is clear.

Net yield in the 1997/98 season, on a log-transformed scale, demonstrated a significant relationship with the number of plants killed by *Fusarium* wilt ($p = 0.003$). Low yields occur even when damage levels are low, possibly due to other causes such as low fertility levels or poor farm management. However when damage levels are high, yields are clearly reduced to a considerable extent.

ICEAP 00040 is consistently the best performer in 1997/98 and 1998/99 in terms of overall yields, deaths due to diseases (in general), and deaths due to *Fusarium.* The seed size is larger than any of the other varieties except ICEAP 00053 while the number of seeds per pod approaches levels found in ICP 9145.

ICP 9145 is a reliable pigeonpea variety with outstanding yield and wilt-resistance. However seed size, although variable, is generally small compared with the ICEAP varieties, and slightly smaller than even the local variety. In addition ICP 9145 is difficult to process due to its hard seed coat which is not easy to detach (Patel 1998).

Yield of ICEAP 00053 showed great variation between years, being intermediate between those of ICEAP 00040 and ICP 9145 in 1998/99, but little more than that of the local in 1997/98. The average number of seeds per pod was also found to be consistently lower

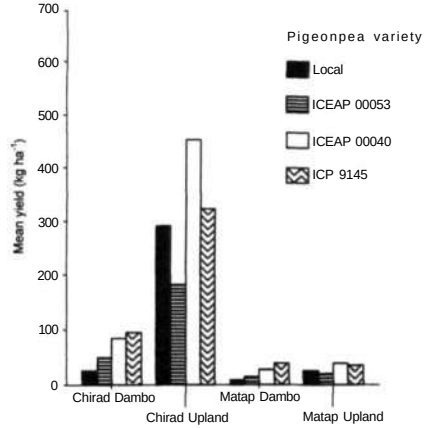

Figure 1. Net yield (kg ha^{-1}) of pigeonpea genotypes across locations and varieties (1997/98).

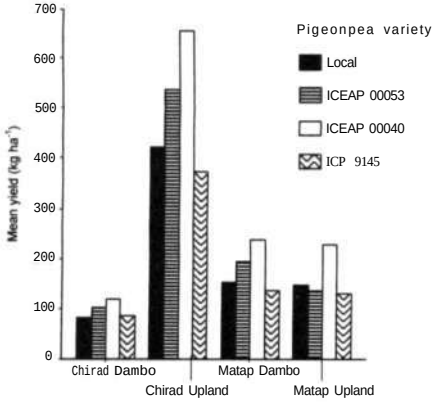

Figure 2. Net yield (kg ha^{-1}) of pigeonpea genotypes across locations and varieties (1998/99).

than for the other three varieties. Seed size, however is the same as ICEAP 00040. The main disadvantage of this variety lies in its apparent susceptibility to *Fusarium* that is comparable with that of the local variety.

From these results it can unequivocally be recommended that ICEAP 00040 is suitable for release in Blantyre Shire Highlands and can be expected to deliver significant benefits to smallholders. Farmer satisfaction is also high on taste, seed size, yield, firewood, and marketability (Mwale and Ritchie 1998). ICEAP 00040 is preferred by *dhal* processors because of its large pale seeds and easily removed seed coat. Processors have indicated that they would like to see ICEAP 00040 replace ICP 9145 as soon as possible. However, the superior performance of ICP 9145 in respect of pod pest damage (Ritchie et al. 2000) suggests that it may continue to have value to smallholders in avoiding serious yield losses in years when pod pest populations are high, until such a time as resistant varieties or other pest management strategies become available to address this problem.

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Increasing Pigeonpea Productivity by Providing Land Configuration in Vertisols

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Pigeonpea is mainly grown as a rainy season crop in south Gujarat. Its productivity is low during this season mainly due to water logging condition, poor plant stand, excessive weed population, and high incidence of pests and diseases. South Gujarat falls under high rainfall area (1500-2500 mm) and the majority of soils (Typic Chromusterts) are high in clay content (40-60%) exhibiting poor physical soil parameters. The prospect of increasing productivity of this crop seems to be bright if it is saved from waterlogging during rainy season. The present experiment was undertaken to ascertain beneficial effect of providing surface drainage through land configuration treatments, if any, on crop yield.

The study was undertaken at Pulse Research Station, Gujarat Agricultural University, Navsari, Gujarat during rainy seasons of 1996-97 to 1998-99. Five land configuration treatments—flat bed, ridge and furrow, 1 furrow after 2 rows, 1 furrow after 3 rows, and 1 furrow after 4 rows—were employed in randomized block design with 4 replications. The plot size was 7.5 m x 5.0 m accommodating 10 rows spaced 75 cm apart. Two meter border

Table 1. Effect of different land configuration treatments on grain yield and economics of pigeonpea crop.

Treatments	Grain yield (t ha^{-1})				Gross income (Rs ha^{-1})	Gross expenditure (Rs ha^{-1})	Net return (Rs ha^{-1})	Benefit: cost ratio
	1996-97	1997-98	1998-99	Mean				
Flat bed	1.82	1.65	1.57	1.68	26 880	8 500	18 380	2.16
Ridge and furrow	2.33	1.71	1.97	2.00	32 000	8 860	23 140	2.61
1 furrow after 2 rows	2.81	1.74	2.20	2.25	36 000	8 680	27 320	3.15
1 furrow after 3 rows	2.93	1.90	2.67	2.50	40 000	8 620	31 380	3.64
1 furrow after 4 rows	3.09	2.05	2.81	2.65	42 400	8 620	33 780	3.92
CD at 5%	0.34	0.21	0.28	0.42				

Average price of pigeonpea grains: Rs 16 000 t^{-1}.

area was left around all the plots and drainage furrows were provided along these plots, except control (flat bed method), for removal of excess water. The crop was fertilized with 20 kg N and 40 kg P_2O_5 ha^{-1}. The crop received total rainfall of 1210 mm in 1996-97, 1139 mm in 1997-98, and 1559 mm in 1998-99. The grain yield data was analyzed statistically for treatment comparison. Net realization and benefit as compared to cost ratios were worked out based on the average yield of 3 years.

The results (Table 1) revealed significant effect of different land configuration treatments on grain yield of pigeonpea. Providing 1 furrow after 4 rows of pigeonpea (Fig. 1) recorded highest grain yield (2.65 t ha^{-1}) which was significantly superior to flat bed as well as ridge and furrow sowing during all the three years as well as in pooled analysis. This treatment was statistically on par with providing 1 furrow after 3 and 2 rows of pigeonpea in pooled analysis. Better yields under these treatments can be attributed to the better plant stand up to maturity (91-97%), which was considerably reduced under flat bed and ridge and furrow method (52-84%). Providing furrows in these treatments would have also helped in maintaining optimum moisture supply in the effective root zone, which improves physical, chemical, and biological properties of soil, which ultimately results in higher yield. The results corroborate the findings of Mamo et al. (1994) who recorded significantly higher grain yield of gram with broad bed furrow method of sowing than sowing on flat seed beds. Sengar (1998) has also reported benefical effect of surface drainage on pigeonpea during the rainy season under clay loam soil condition of Jagdalpur, Madhya Pradesh, India.

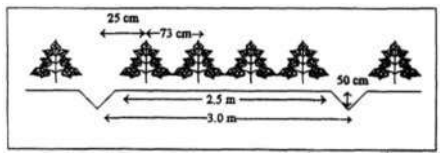

Figure 1. Diagram showing furrow after 4 rows.

Economic evaluation of different treatments showed highest net realization (Rs 33 780 ha^{-1}) and benefit : cost ratio (3.92) under the treatment involving 1 furrow after 4 rows.

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Variation in Starch, Total Soluble Carbohydrates and Reducing Sugars During Germination of Redgram (*Cajanus cajan* L.)

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Changes in starch, total soluble carbohydrates, and reducing sugars were determined in germinating seeds of redgram. Starch was found to be increased in shoot but decreased in endosperm as a result of germination. However, total soluble carbohydrate was found to be decreased both in shoot and endosperm whereas the reducing sugar showed an increase both in shoot and endosperm till the fourth day of germination which decreased gradually on the following days of investigation.

Redgram also called pigeonpea (*Cajanus cajan* L.) occupies an important place in human nutrition as a rich source of protein in the diet of consumers in India. It is a valuable source of minerals and vitamins and occupies a very important place in the diets of many developing countries (Singh 1988). Redgram is an important grain legume commonly grown and consumed in tropical and subtropical regions of the world. India accounts for over 90% of the world's supply of redgram (Singh 1993). This paper describes the changes in starch, total soluble carbohydrates, and reducing sugars during germination of redgram.

Materials and Methods

Redgram seeds were procured from pulse research station, Gulbarga. Seeds of uniform size were washed in running tap water for 12 h to facilitate germination. Seeds were then surface sterilized by treating with 0.1% mercuric chloride. The sterilized seeds were washed with distilled water and soaked overnight at 4°C. The soaked seeds were placed on moist filter paper in petri plates and incubated at 37°C in the dark. The seeds were moistened with distilled water at regular intervals. The germinated seeds were harvested at 24 h intervals and used. Starch and total soluble carbohydrates were determined by the Clegg (1966) method while reducing sugar was estimated by the Nelson-Somyogi method (1957).

Results and Discussion

Table 1 shows data on starch content during germination of redgram. The starch content in endosperm decreases as the days of germination increases whereas it increases in the shoot with increase in the days of germination. Similar decrease in starch content is observed during germination of bengalgram and greengram (Jaya and Venkatraman 1980). The decrease is due to the fact that the starch stored in the endosperm is broken down to simple sugars during germination. The increase in starch content in shoot is because starch is being deposited in the shoot from simple sugars during germination.

Results of changes in total soluble carbohydrates during germination of redgram are represented in table 2. A decrease in total soluble carbohydrates is observed both in shoot and endosperm as the days of germination increases. Our results are in agreement with those observed by Jaya and Venkatraman 1980. The decrease may be due to the fact that they are energy sources during the

Table 1. Changes in starch contents during germination of redgram (*Cajanus cajan* L.).

Days to germination	Starch content (μg g^{-1})					
	Shoot	±	SD	Endosperm	±	SD
1	16.20	±	0.41	180.00	±	0.18
2	21.60	±	0.11	144.00	±	0.50
3	27.00	±	0.11	90.00	±	0.25
4	48.60	±	0.45	77.40	±	0.40
5	90.00	±	0.64	36.00	±	0.30

SD = Standard deviation.
Each value is an average of triplicate determination.

Table 2. Changes in total soluble carbohydrates during germination of redgram (*Cajanus cajan* L.).

Days of germination	Total soluble carbohydrates (mg g^{-1})					
	Shoot	±	SD	Endosperm	±	SD
1	140.00	±	0.14	200.00	±	0.16
2	100.00	±	0.82	160.00	±	0.54
3	80.00	±	0.30	100.00	±	0.54
4	50.00	±	0.24	80.00	±	0.44
5	ND			70.00	±	0.42

SD = Standard deviation.
ND = Not detected.
Each value is an average of triplicate independent determination.

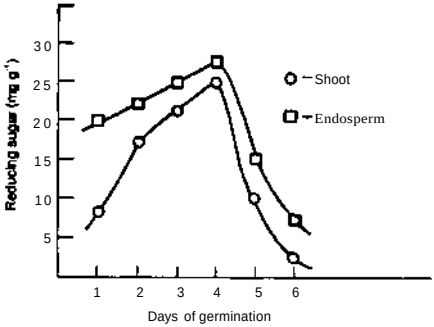

Figure 1. Changes in reducing sugars during redgram germination.

early stages of germination and are utilized for respiration and incorporation into cellwalls for translocation to the growing axis.

Figure 1 represents the changes in reducing sugars during germination of redgram. Reducing sugars increase both in shoot and endosperm till fourth day of germination and decrease gradually on the following days of investigation. Increase in reducing sugars during germination of bengalgram and greengram is reported by Jaya and Venkatraman. Morahashi (1982) has reported that reducing sugar content continues to increase both in attached and detached cotyledons, the increasing rate being greater in detached than in attached cotyledons. Sharma and Pant (1978) have observed an initial rise in germination time of redgram.

Conclusion

It can be concluded that there is variation in starch, total soluble carbohydrates and reducing sugars during germination of redgram. The decrease in starch may be due to its breakdown to simple sugars whereas the decrease in total soluble carbohydrates may be due to the fact that they are energy sources during early stages of germination.

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Effect of Soaking and Germination on Oligosaccharide Content of Redgram

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Legumes and cereals are relatively inexpensive source of protein and energy for the developing countries including India. Pigeonpea is one of the important grain legumes of India and is a valuable source of protein, minerals, and vitamins for human nutrition. Pigeonpea is also known to contain several antinutritional factors including alpha-galactosides (Singh 1988), which include raffinose, stachyose, and verbascose and they constitute 53% of total soluble sugars. The raffinose family of sugars cannot be hydrolyzed and absorbed, because of alpha-galactosidase activity in the small intestine. Microorganisms present in the large intestine utilize these sugars and lead to flatus formation (Olson et al. 1981). Redgram is consumed after processing including traditional process like hot soaking and germination. This study reports the distribution and changes in the oligosaccharide content during germination

of two varieties of redgram grown in Gulbarga, Karnataka.

Redgram seeds grown locally were obtained from Pulse Research Center, Gulbarga. Oligosaccharide concentration was determined in 1 g of powdered redgram flour according to the method of Tanaka et al. (1975). Hot soaking was done by placing 100 g of redgram seeds in boiling water for 5 min and allowing it to reach a temperature of 50°C (about 1 h). The effect of hot soaking of redgram seeds on the oligosaccharide content led to a mean decrease of 78% for raffinose, 76% for stachyose and 78% for verbascose (Fig. 1). The levels of the raffinose family of sugars decreased with the increasing duration of hot soaking.

Both the levels of total soluble and reducing sugar content decreased during hot soaking of redgram (Fig. 2). The hot soaking led to a mean decrease of 67% for total soluble sugars and a mean increase of 86% for reducing sugars.

Soaking followed by germination of redgram seeds led to complete removal of raffinose family sugars, i.e. raffinose, stachyose, and verbascose (Table 1). Mulimani et al. (1996) have reported that soaking of whole soybean seeds for 16 h led to a mean decrease of 80% for raffinose and 45% for stachyose. The drop in the levels of raffinose family sugars during hot soaking is because of leaching of the raffinose family sugars into the water. Upadhyay and Garcia (1988) have demonstrated that leaching of the raffinose family sugar from cowpea seeds during soaking could be attributed to: (a) the differential solubility of individual sugars and (b) their diffusion rates. The decrease in the raffinose family sugar content during soaking followed by germination is believed to be with increase in the alpha-galactosidase activity (Kawamura 1964). Nigam and Giri (1961) have reported increase alpha-galactosidase activity in germinated pulses which is responsible for the decreased oligosaccharide content of germinated pulses.

Soaking of redgram followed by germination led to a mean increase of 65% for total soluble sugars and decrease of 31% for reducing sugars (Table 2). During soaking followed by germination the non-reducing raffinose family sugars are degraded by alpha-galactosidase leading to the release of sucrose and D-galactose. Further, the released D-galactose is phosphorylated and further metabolised to generate energy for the developing seedlings.

The present results show that soaking followed by germination could be used to alleviate the levels of flatulence inducing raffinose family sugars, thereby improving the nutritional quality of redgram. The method is simple,

Table 1. Oligosaccharide content of redgram flour (g per 100 g dry basis) after soaking followed by germination[1].

		Soaking followed by germination (h)					
Variety	Raw	4	8	12	16	20	24
				Raffinose			
Local 1	1.26	0.93	0.61	0.84	0.49	0.43	ND
Local 2	1.58	0.93	1.00	0.94	0.58	0.66	ND
Mean ± SD	1.42	0.93	0.80	0.89	0.53	0.54	ND
	±0.22	±0.00	± 0.27	± 0.07	±0.06	±0.16	ND
				Stachyose			
Local 1	1.72	1.14	1.09	0.79	0.45	0.42	ND
Local 2	1.78	1.18	0.72	0.79	0.26	0.63	ND
Mean ± SD	1.75	1.16	0.90	0.79	0.36	0.53	ND
	±0.04	±0.02	±0.26	±0.00	±0.13	±0.14	ND
				Verbascose			
Local I	9.20	6.30	4.50	4.50	3.30	1.65	ND
Local 2	9.20	5.70	2.55	4.65	6.60	1.95	ND
Mean ± SD	9.20	6.00	3.53	4.58	4.95	1.80	ND
	±0.00	±0.42	±1.37	±0.10	±2.30	±0.21	ND

1. Each value is average of triplicate determination.
ND = not detectable.
± one SD.

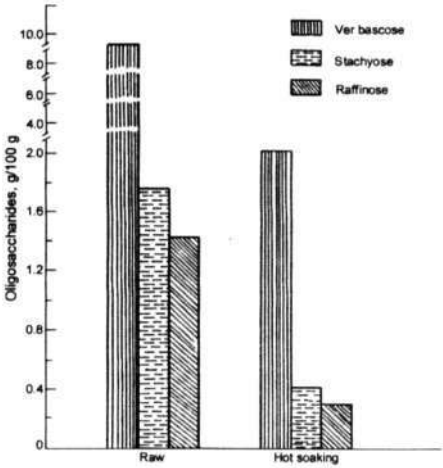

Figure 1. Mean levels of verbascose, stachyose and raffinose in redgram before and after hot soaking (1 h).

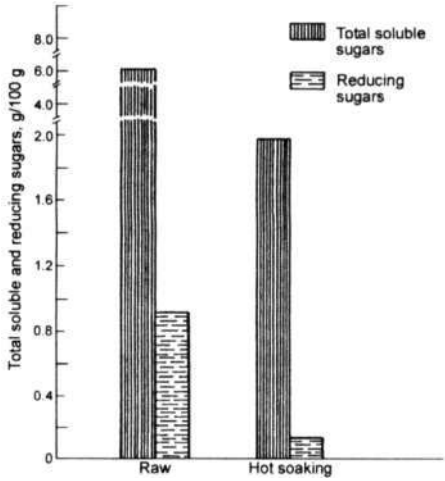

Figure 2. Mean levels of total soluble sugars and reducing sugars in redgram before and after hot soaking (1 h).

Table 2. Total soluble sugar and reducing sugar content of redgram flour (g per 100 g dry basis) after soaking followed by germination[1].

		Soaking followed by germination (h)					
Variety	Raw	4	8	12	16	20	24
				Total soluble sugars			
Local 1	6.72	9.36	9.30	9.30	10.12	9.30	10.12
Local 2	5.64	9.36	9.36	9.36	9.36	10.12	10.12
Mean ± SD	6.18	9.36	9.33	9.33	9.74	9.71	10.12
	±0.76	±0.00	±0.04	±0.04	±0.53	±0.57	± 00.00
				Reducing sugars			
Local 1	0.86	0.16	0.24	0.38	0.40	0.60	0.66
Local 2	0.96	0.12	0.20	0.36	0.48	0.48	0.58
Mean ± SD	0.91	0.14	0.22	0.37	0.44	0.54	0.62
	±0.07	±0.02	±0.02	±0.01	±0.05	±0.08	±0.05

1. Each value is average of triplicate determination.
± one SD.

easy and inexpensive for reduction of oligosaccharides of redgram.

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Detection of Protease Inhibitory Activity in Legumes Using X-Ray Film

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Pulses are second to cereals as a source of human and animal food. Pulses are particularly important in the diet since they contain more protein than cereals. Pigeonpea (*Cajanus cajan* (L.) Millsp.) is a major legume crop grown by resource poor farmers in many developing countries in semi-arid tropics and subtropics for food, fodder, fuel, and cash.

Pigeonpea and chickpea (Kabuli variety) are important pulse crops of India. They are valuable source of proteins, minerals, and vitamins. However they are known to contain anti-nutritional factors (ANFs) (Singh 1988). Sohonie and Bhandarkor (1954) have reported the presence of trypsin inhibitors in pigeonpea. Godbole et al. (1994) have isolated and purified trypsin and chymotrypsin inhibitors from redgram. Mulimani and Paramjyothi (1992) have observed that some pigeonpea accessions do not contain high levels of trypsin and chymotrypsin inhibitors. Chickpea (*Cicer arietinum)* also contains high amounts of protein and other ANF's like a-amylase inhibitors, tannins, etc. (Singh 1988). This study reports the detection of protease inhibitors of pigeonpea pods and chickpea (Kabuli variety) on an unprocessed x-ray film.

Materials and Methods

The legume seeds were procured from Agriculture Research Station (ARS), Gulbarga. The enzymes trypsin and chymotrypsin, enzyme inhibitors like phenylmethyl sulfonylfluoride (PMSF), and Tosyl-lysine chloromethyl ketone (TLCK), Tosyl-phenylalanine chloromethyl ketone (TPCK) were purchased from Sigma Chemical Co., St. Louis, USA. Nitrocellulose membrane was purchased from Bio-Rad. Both processed and unprocessed x-ray films were purchased at a local x-ray diagnostic centre (Konica) and all other chemicals used were of analytical grade.

Acetone defatted meal of pigeonpea pods and chickpea (Kabuli) were prepared by soaking the seeds in distilled water at 4°C for 12 h and homogenized with chilled acetone in a blender followed by filtration using suction and rapid air drying. The flour obtained (50 g) was stirred with 150 ml of sodium phosphate buffer pH 7.6 for 4 h at 5°C with occasional stirring. The mixture was centrifuged in a Hitachi centrifuge at 12,000 rpm (17.7 g) for 15 min at 4°C. The clear supernatant obtained (20 mL) was dialyzed against 0.05 M phosphate buffer pH 7.1 overnight. The buffer was changed every 4 h. The dialyzed extract obtained was used for the inhibitory assay by modified case in digestion method.

Results and Discussion

Dilutions of trypsin to an activity of 2000 BAEE units, was made in sodium phosphate buffer, pH 7.6. These dilutions were in the concentration range of 0.02 ug mL^{-1}

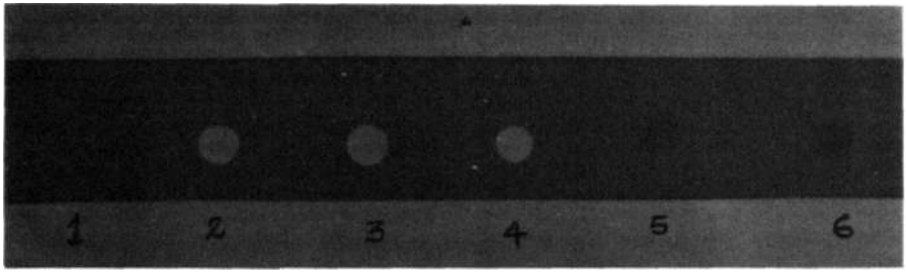

Figure 1. Digestion of gelatin coated onto x-ray film with trypsin. Trypsin at various concentration in sodium phosphate buffer (0.2 µg mL^{-1} to 0.8 µg ml^{-1}) was applied (50 µl) onto a x-ray film and incubated at 42°C for 1 h. After incubation the x-ray film was washed with running water to produce clear zones. The fifth spot depicts the inhibition of trypsin by PMSF. The sixth spot depicts the inhibition of protease by pigeonpea pod inhibitor.

Spot 1 Buffer (control) 50 µl; Spot 2 Trypsin (0.8 µg mL^{-1}) 50 µl; Spot 3 Trypsin (0.4 µg mL^{-1}) 50 µl; Spot 4 Trypsin (0.2 µg $ml,^{1}$) 50 ml; Spot 5 Trypsin (0.6 µg ml) + 10 mM PMSF 50 ml; Spot 6 Trypsin (0.4 µg ml) + 5 µl of pigeonpea pod protease inhibitor extract.

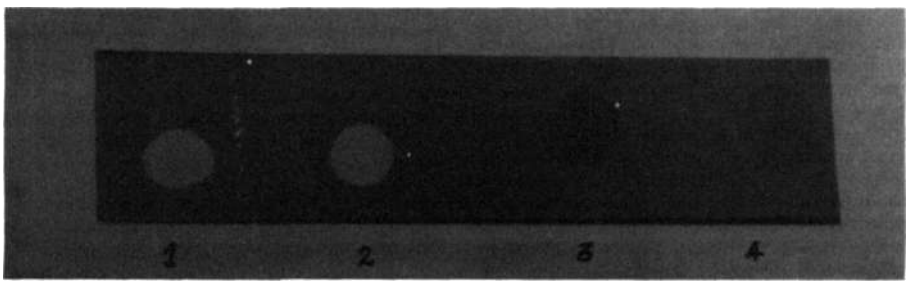

Figure 2. Variations on dot-blot using protease/inhibitor: The nitrocellulose membrane with a protease solution, a reference solution (BSA) and inhibitor extract were spotted onto an x-ray film after incubating in protease solution. The spots 1 and 2 correspond to trypsin and BSA solution. Similarly the spots 3 and 4 are of inhibitor extract of chickpea (Kabuli variety) mixed with equal quantities of protease solution.

Spot 1 Trypsin solution (0.6 µg mL^{-1}) 20 µl; Spot 2 BSA (1 pg $mL,^{-1}$) 20 µl; Spot 3 Trypsin solution (0.4 pg mL^{1}) + 5 µl of chickpea protease inhibitor extract; Spot 4 Trypsin solution (0.4 pg mL^{-1}) + 10 µl of chickpea protease inhibitor extract.

to 1 pg mL^{-1}. The above serially diluted trypsin solution was used to study its effect on gelatin substrate. Figure 1 depicts the digestion of gelatin coating on x-ray film. The spots 1,2,3, and 4 refer to buffer (control), serially diluted trypsin solution of 0.2 pg mL^{-1}, 0.4 µg mL^{-1} and 0.8 ug mL^{-1} respectively. These spots depict a clear zone formed after the digestion of gelatin on the x-ray film. The fifth spot depicts trypsin 0.6 µg mL^{-1} mixed with 10 mM PMSF. It did not produce a clear zone under similar conditions. The sixth spot corresponds to pigeonpea pod extract (5 ul) which, when mixed with 0.4 µg mL^{-1} of trypsin solution, did not digest the gelatin coating on the x-ray film. The reaction was carried out in an incubator at 42°C.

Figure 2 shows the dot-blot assay to detect protease inhibitors of chickpea (Kabuli variety). The spots 1 and 2 in photograph correspond to trypsin 0.6 µg mL^{-1} and bovine serum albumin (BSA) as reference. The spots 3 and 4 refer to varying quantities of inhibitor extract such as 5 ul and 10 ul which, when mixed with an equal

quantity (5 µl and 10µl) of trypsin solution, inhibits the trypsin (0.4 µg mL^{-1} concentration).

The composition of a typical x-ray film consists of acetate cellulose coated on both sides with an emulsion of silver halide and gelatin. This preparation is applied onto various sizes of plastic sheets on both sides. Cheung et al. (1991) have described a similar method to detect proteinase activity and also studied the effect of commercially available soybean trypsin inhibitor (SBTI) mixed with trypsin. Soybean trypsin inhibitor of 2 µg mL^{-1} were added to samples of trypsin at 1 ug mL^{-1} to demonstrate inhibition of trypsin by SBTI. They have also compared the protease activity by spotting dilutions of trypsin on x-ray film. Pichare and Kachole (1994) have used the dot-blot technique to detect the electrophoretically separated protease inhibitors using x-ray film. The detection was done for different legumes. The lowest amount detected was 2 mL of acid seed flour extract of pigeonpea. The dot-blot technique is widely used to detect nucleic acids and proteins. It is usually done with a pipette or by filtering it through a special apparatus by means of suction. The sample is normally applied in the circular form (dot). The nitrocellulose membrane has a high binding capacity for proteins and good staining characters. Nitrocellulose membranes provide excellent resolution and are easy to handle.

The dot-blot technique described above is very useful as the inhibitor extract is spotted directly onto a nitrocellulose membrane in different quantities. The samples are allowed to dry and this nitrocellulose membrane is rinsed in tris buffered saline (TBS) pH 7.1 for 15 min. It is then rinsed in 0.1% trypsin solution for another 15 min, rinsed briefly in TBS and spotted on x-ray film. Then the film is washed under tap water to get clear zones. The dot-blot method is convenient when a large number of samples are to be screened for the presence of protease inhibitors. Detection of inhibitors by mixing protease/inhibitor and spotting on the x-ray film and checking clearance of film (Cheung et al. 1991) requires individual mixing of protease and inhibitor sample before spotting on the x-ray film. In order to detect lower levels of inhibitors, protease and sample need to be mixed again in different proportions. In dot-blot both these difficulties can be overcome, as the inhibitor is spotted directly on nitrocellulose membrane, and incubated with protease solution. The same nitrocellulose membrane can be placed on another piece of x-ray film for a shorter time to compare the results obtained. The inhibitor can also be detected by using photographic paper (data not shown) but the incubation time with nitrocellulose membrane takes a longer time to detect the spots.

We have used x-ray film method and dot-blot method to detect protease inhibitors extracted from pigeonpea pods and chickpea (Kabuli variety). The studies show it is a easy, rapid and inexpensive. The results are obtained in 1 h. This assay can be performed by laboratory personnel with minimal training. Also this experiment does not require any costly techniques and chemicals. The method can be useful when large samples are to be screened for their protease inhibitory activity.

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Utilization

Water Utilization of Pigeonpea Used as Forage vs Grain

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A basic goal of many grazing programs is to provide high quality forage year-round to reduce cost of using stored or purchased feed. The primary forage resource for livestock in the southern Great Plains is wheat pasture during winter and spring, and warm-season perennial grasses in the summer. A void in forage production in this system exists from late-August to November. In order to be sustainable, future forage and livestock production systems must involve the use of all possible forage sources including legumes to fill the forage deficit period.

Pigeonpea (*Cajanus cajan* L. Millspaugh) is one of the major grain legume crops of the tropics and subtropics and it ranks sixth in area and production when compared with grain legumes such as soybeans (*Glycine max* L.), peas (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.), and groundnut (*Arachis hypogaea* L.). Unlike other grain legumes, pigeonpea can simultaneously satisfy the needs for human food and feed for animals. A unique feature of pigeonpea is drought tolerance compared to other grain legumes. The potential of pigeonpea to produce a very high biomass is demonstrated by producing 40 t ha^{-1} dry matter from one cutting of late maturing pigeonpea at Kanpur, in northern India (Singh and Kush 1981). Herrera et al. (1966) observed 57.6 t ha^{-1} biomass yield for pigeonpea in Columbia. These yields are highest recorded for a forage legume, even higher than 'Leucaena leueocephala', and equivalent to high yielding tropical grasses. However, actual yield of edible forage is probably about 50% of these amounts because of woody stem (Whiteman and Norton 1981). Tests by Henke et al. (1940) suggested that forage of pigeonpea was superior to grasses. Whiteman and Norton (1981) indicated that pigeonpea forage had higher nutritive value index and could carry higher stocking rates than other grasses tested. Akinola and Whiteman (1975) reported that highest N content are found in the leaf fraction (3.64%) while N content in the stem decline quickly from 2.76% to 1.5% as the stem dry matter increased. However, knowledge on water utilization by pigeonpeas during summer fallow period of winter wheat in the southern Great Plains is unknown. The objective of this study is to determine the impact of clipped and undipped pigeonpeas on the depletion of soil water profile.

After winter wheat harvest (June), land was ploughed and 60 kg of phosphorus was suface broadcast and disked. Pigeonpea seed (Georgia-2) was inoculated with pea inoculm and seeded @ 25 kg ha^{-1} with a row spacing of 60 cm and 15 cm apart within row. Treatments include: clipping top half of the plant at flowering and undipped. Soil water content at 4 different depths were measured periodically using 'Time Domain Reflectometer (TDR)'.

Total precipitation received during the active growth period (August and September) in 1998 was 12.6 cm below the 25-y average. However, in October and November the total precipitation was 17.1 cm greater than 25-y average. The mean monthly temperatures were similar to the 25-y average except for August and September (Fig. 1).

Soil profile moisture in the 0-15 cm depth during August and September were similar for undipped and fallow plots and slightly lower in clipped plots. October precipitation recharged the 0-15 cm soil profile resulting in greater soil moisture content in fallow plots (Fig. 2). At 15-30 cm depth more soil water was utilized during the active growth period: 6% as compared to fallow plots. Below 30 cm no significant differences in soil moisture were observed. This suggests that roots of pigeonpea did not penetrate below 30 cm due to dry conditions.

Total plant biomass production at final harvest between undipped treatments was 250 g $plant^{-1}$ and clipped

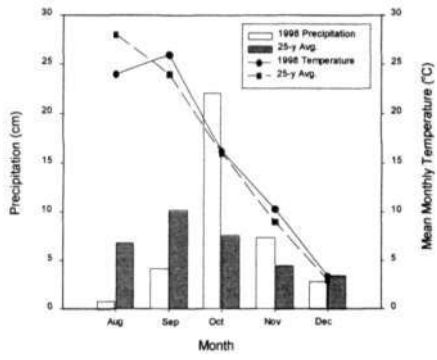

Figure 1. Precipitation and mean monthly temperatures from Aug to Dec 1998 and 25-y Avg.

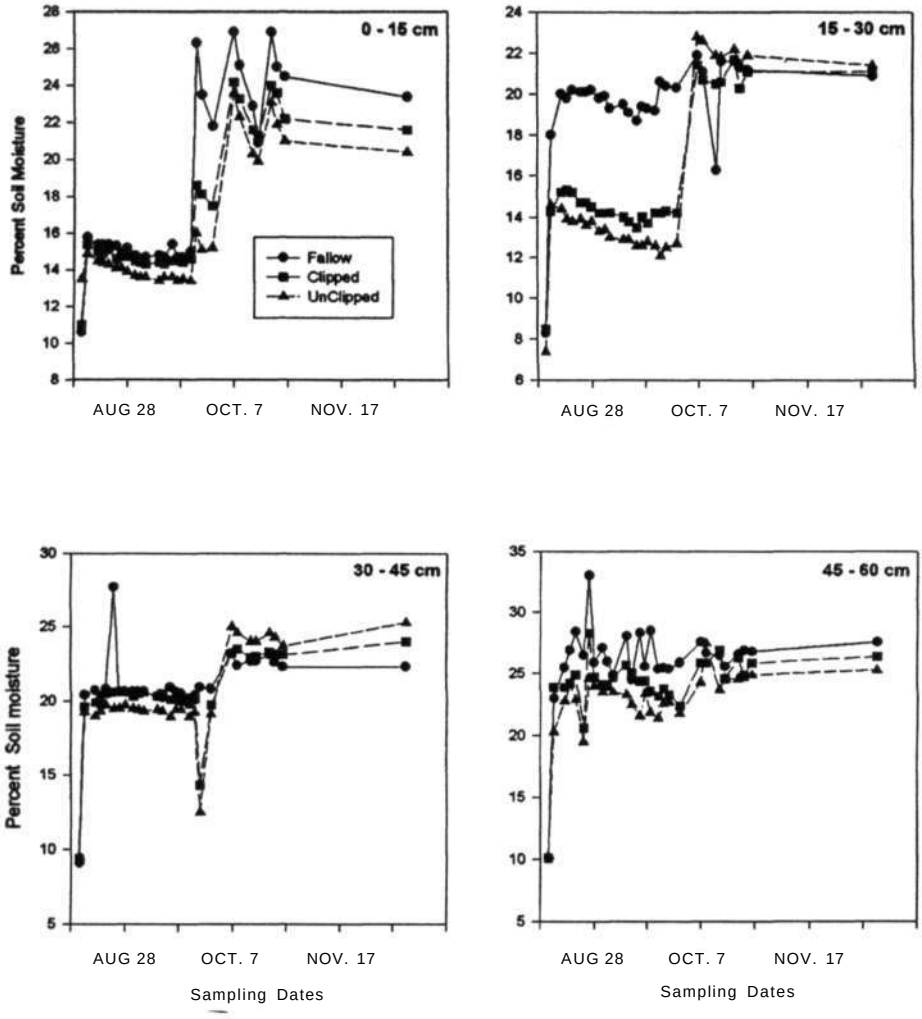

Figure 2. Soil moisture (%) at 0-15, 15-30, 30-45, 45-60 cm.

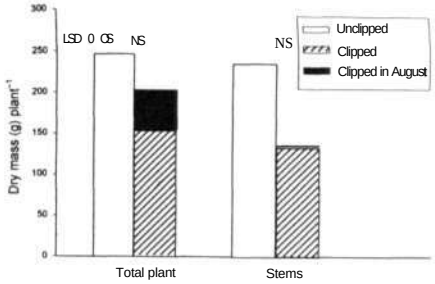

Figure 3. Total plant mass and stem mass at final harvest.

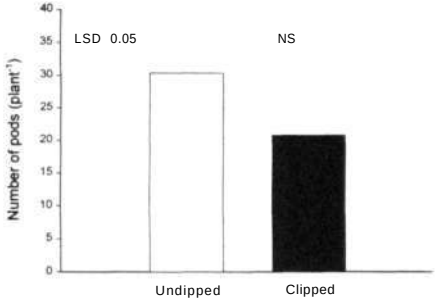

Figure 4. Pods per plant at final harvest.

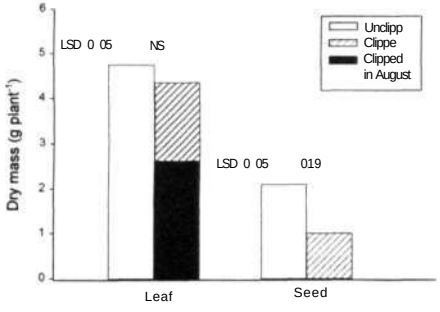

Figure 5. Leaf and seed mass at final harvest

treatments was 205 g plant[1] (Fig. 3). Stem biomass in undipped plots was 57% greater than clipped plots. Removal of top one-third portion of the plant in August resulted in reduced stem mass as compared with undipped plots. Final leaf yield for both clipped and undipped treatments were similar. However, leaf to stem ratio for clipped plots were 1:30 as compared with 1:50 for undipped plots. This suggests that removal of leaf in clipped plots resulted in more leaf biomass production than undipped plots. Number of pods per plant for undipped plots were 45% more as compared with clipped plots (Fig. 4). Seed yield (Fig. 5) at final harvest was significantly greater in undipped plots than clipped plots. However, the difference in leaf biomass was not different among treatments. This increase in grain yield could be attributed to increase number of pods per plant.

Although both treatments utilized more soil moisture from 15-30 cm depth, these results suggest that pigeonpea had little effect on the surface soil moisture. Both treatments exhibited similar total plant biomass, stem, and leaf, whereas, grain yield in undipped plots were greater than clipped plots. Overall, pigeonpea did not significantly affect the soil moisture availability for the establishment of winter wheat in the southern Great Plains Region.

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An Optimal Medium for *In vitro* Pollen Germination of Pigeonpea (*Cajanus cajan* L. Millsp.) Genotypes

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In vitro pollen germination is an effective technique to determine the viability of pollen and has many potential applications in pollen biology (Heslop-Harrison 1987, Shivanna and Sawhney 1997). The medium used for pollen germination varies with species and are described in detail by Shivanna and Rangaswamy (1992). Among the various media reported so far, the one developed by Brewbaker and Kwack (1963) has been used widely and found suitable for over 86 species of different taxa. In pigeonpea, there were only two reports available on pollen germination *in vitro.* But to date no complete medium for pigeonpea is reported. James et al. 1987 reported 48.7% pollen germination at 28°C in a medium containing sucrose 40%, boric acid 250 mg L^{-1}, calcium nitrate 200 mg L^{-1}. Later Singh et al. (1992) modified the above said medium by adding 0.7% agar and obtained 43% germination at 22°C.

Table 1. *In vitro* pollen germination of *C. cajan* var. Pusa 33 in 5 different BK media[1] containing PEG 4000.

Medium	Concentration of: Boric acid (ppm)	Concentration of: Calcium nitrate (ppm)	Germination (%)
BK 1	200	300	53.70
BK 2	250	300	87.44
BK 3	300	300	74.52
BK 4	250	200	66.75
BK 5	250	400	87.25

1. 37.5% sucrose +15% PEG + other BK salts arc constant for all media.

Table 2. Percent pollen germination of *C. cajan* genotypes in medium BK 2 and their best pollen germination medium (PGM).

Genotype	% Germination in BK 2 medium	Germination (%): Best medium[1]	Germination (%): % germination
Pusa 33	73.26	P_4	91.09
F1 (3D 8103 x SP13)	89.55	BK 2	89.55
DTSP 14	0.0	P_2	78.27
DTSP 15	46.04	P_1	99.07
DTSP 30	93.58	BK 2	93.58
DTSP 48	68.50	BK 2	68.50
IDTSP 51	98.40	BK 2	98.40
1CP 8504	64.71	P_3	80.45

1. P_1 to P_3 -PGM with EACA for BK medium see Table 1.

In our experiment agarified (1% agar) Brewbaker and Kwack (BK) medium was used as basal medium and polyethylene glycol (PEG) 4000 and/or e-amino caproic acid (EACA) was added to the media, if necessary. Initial experiments were conducted with *Cajanus cajan* var. Pusa 33 grown under field conditions. Pollen collection and culture was done following the findings of Singh et al. (1992). In the preliminary experiments, a maximum of 43.8% pollen germination was obtained in a BK medium (40% Sucrose + 250 ppm boric acid + other BK salts + l%agar) at 20.5°C. Other permutation and combinations of media components failed to improve germination beyond 43%. In the second experiment, BK media with 15% PEG 4000 were tried. Pollen of Pusa 33 showed 53-87% germination in BK media containing 200-300 ppm boric acid and 200-400 ppm calcium nitrate (Table 1). The medium BK 2 showed 87% germination with maximum normal pollen tubes as compared to other media. Varying the concentrations of boric acid and/or calcium nitrate failed to improve germination rate. Pretreatment of pollen such as prehydration (keeping pollen in a petri dish lined with moist filter paper for 30 min) or heat treatment (60°C for 20 min or 40°C for 30 min) also did not help.

Addition of EACA (e-amino caproic acid) to the medium BK 2 improved germination rate. Different levels of EACA (100, 250, 500, 750, 1000 mg L^{-1}) were added to the pollen germination medium BK 2 and media P_1-P_5 were obtained. Pollen of Pusa 33 showed >90% germination in media containing EACA at the concentrations of 750 or 1000 mg L^{-1}. To confirm the effect of EACA on

pollen germination eight other randomly selected genotypes were tested in P_1—P_5 and BK 2 media. The genotype IDT SP 51 showed as high as 98.4% germination in the medium BK 2. The genotypes, which, recorded low percent germination in BK 2 showed improved germination with addition of EACA but the level varied with genotypes (Table 2). The results indicate that PEG and EACA are essential for pigeonpea pollen germination *in vitro*. Thus, the complete pollen germination medium for pigeonpea genotypes contains sucrose 37.5% + PEG 15% + boric acid 250 mg L^{-1} + calcium nitrate 300 mg L^{-1} + magnesium sulfate 200 mg L^{-1} + potassium nitrate 100 mg L^{-1} + agar 1% + EACA (0-1000 mg L^{-1}).

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Standardization of *In vitro* Pollen Germination Media for Two Wild Species of Pigeonpea

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The pigeonpea wild species, *Cajanus platycarpus* and C. *volubilis* belong to the tertiary gene pool (van der Maeson 1990). *C. platycarpus* possesses many desirable characters like photo-insensitivity, annuality, resistant to phytophthora blight, pod borers, etc., whereas C. *volubilis* has high seed protein content and resistance to sterility mosaic (Kumar et al. 1990). However, reproductive barriers prevent the gene transfer from these wild species to cultivated pigeonpea. Standardization of *in vitro* pollen germination would be helpful in interspecific hybridization in a number of ways; it is a prerequisite for *in vitro* pollination and fertilization. James et al. (1987) developed a pollen germination medium for C. *platycarpus*. However, for C. *volubilis* there were no such reports.

In the present study Brewbaker and Kwack (BK) (1963) medium was used as basal medium for pollen germination. Seeds were sown in the month of June and *in vitro* pollen germination studies were carried out during September-October, and March of 1997-98 at New Delhi (29°N; 77° 22 E). The seeds were scarified before sowing. Pollen collection and culture was done as suggested by Shivanna and Rangaswamy (1992). Initially agarified (1% agar) BK media with sucrose at four levels (10%, 20%, 30%, 40%) were tried. C. *platycarpus* showed 99% germination (Fig. 1) and mean pollen tube length of 173 mm in a BK medium containing 20% sucrose after 1 h incubation. At 10% sucrose level there was substantial reduction in percent germination whereas at 30%, pollen tube length was reduced drastically (Table. 1). The optimal temperature was 20.5°C for *C. platycarpus* pollen germination. James et al. (1987) used a liquid medium for C. *platycarpus* that consisted of 10% sucrose, 100 ppm boric acid, and 300 ppm calcium nitrate. They reported that this medium gave 90% pollen germination at 28°C. Thus it appears that the incubation temperature and other salts of BK medium played a vital role in enhancing pollen germination of this species.

Table 1. *In vitro* germination of pollen and pollen tube growth of *C. platycarpus* in BK media at 3 sucrose levels.

	Medium		
	A (10% sucrose)	B (20% sucrose)	C (30% sucrose)
Pollen germination (%)	61.60 ± 2.7	99.15 ± 1.4	94.25 ± 1.8
Pollen tube length (μm) $\bar{X}$ ± SE	83.88 ± 0.66	172.56 ±0.32	33.31 ± 0.14

Table 2. *In vitro* pollen germination and pollen tube growth of *C. volubilis* in 5 different media.

Medium	Concentration of		% Germination	Mean pollen tube length (μm) $\bar{X}$ ±SE
	Boric acid (ppm)	Calcium nitrate (ppm)		
G	100	300	<20	-
G_1	250	300	62.12 ± 2.9	16.16 ± 0.6368
G_2	300	300	31.03 ± 3.2	-
G_3	250	100	94.56 ± 1.9	27.47 ± 0.3024
G_4	250	200	83.52 ± 2.3	18.42 ± 0.4006

35% sucrose +15% PEG + Other BK salts is constant for all media.

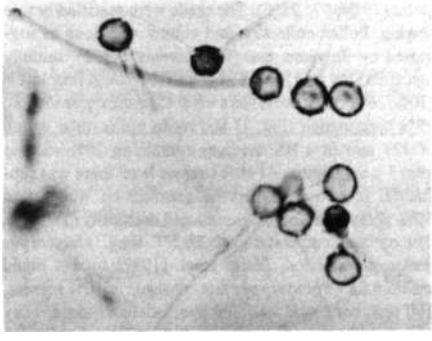

Figure 1. Photomicrograph showing *in vitro* germination of *C. platycarpus* pollen in medium-A containing 10% sucrose after 1 h incubation.

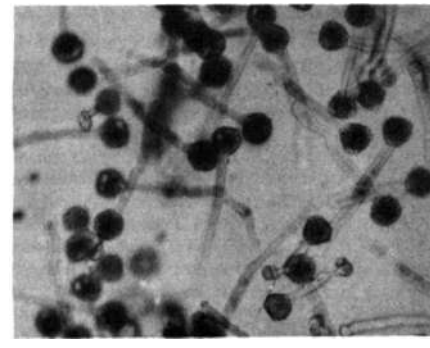

Figure 2. Photomicrograph showing *in vitro* germination of *C. volubilis* pollen in G_3 containing 100 ppm calcium nitrate after 3 h incubation.

C. volubilis pollen did not germinate at 20.5°C in any of the four media mentioned above. In BK medium containing 30% sucrose and 15% PEG showed less than 20% germination. Further, the same medium with different permutations and combinations of boric acid 100, 150, 200, 400 mg L^{-1}) and calcium nitrate (100, 200, 300, 600 mg L^{-1}) were tested. Among them, a set of media showed >60% germination but profuse bursting of pollen/pollen tube was observed. Sucrose level was increased to 35% and incubation temperature was reduced to 18.5°C, which helped prevent bursting of pollen and pollen tubes. The media G_3 containing 100 ppm calcium nitrate recorded 95% germination (Fig. 2) with a mean tube length of 27.47 mm after 3 h incubation (Table 2). Increasing calcium concentration beyond 100 ppm resulted in pollen tube bursting as well as reduction in pollen tube length. Thus a complete pollen germination medium for C. *volubilis* consisted of 35% sucrose + 15% PEG 4000 + 250 ppm boric acid + 100 ppm calcium nitrate + 200 ppm magnesium sulfate + 100 ppm potassium nitrate + 1% agar.

C. volubilis pollen requires PEG 4000 for better germination whereas this is not necessary for *C. platycarpus.* The effect of PEG on improving pollen germination has been reported in many crops but the mechanism is not known. This has also helped to obtain an improvised medium for chickpea (Shivanna et al. 1997). The media developed in this study can be used effectively for experiments on interspecific hybridization of pigeonpea or for *in vitro* pollen selection.

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Ranga Rao, G.V., and Shanower, T.G. 1999. Identification and Management of Pigeonpea and Chickpea Insect Pests in Asia. Information Bulletin no. 57. Patancheru 502 324, Andhra Pradesh, India: ICRISAT. 96 pp. ISBN 92-9066-412-6. Order code IBE057. LDC $13.50. HDC $37.50. India Rs 520.00.

Pigeonpea (*Cajanus cajan* (L.) Millspaugh) and chickpea (*Cicer arietinum* L.) are important grain legumes in Asia. These crops are often heavily damaged by insect pests. Farmers in many areas apply insecticides in an attempt to manage these pests. This bulletin provides descriptions of the most common species, their biology, distribution, and damage symptoms. Color photographs are provided for easy identification. Possible modes of control are also included with an emphasis on integrated pest management and reduced reliance on insecticides.

SATCRIS listings

The following 1999 listings and publications have been generated from ICRISAT's electronic bibliographic database SATCRIS—the Semi-Arid Tropical Crops Information Service. Copies of entries followed by JA or CP numbers can be obtained by writing to:

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Chickpea publications

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Notes

Notes

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