Recent Advances in Research and Management of Botrytis Gray Mold of Chickpea

International Crops Research Institute for the Semi-Arid Tropics

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Abstract

The Fourth Working Group Meeting on Botrytis Gray Mold of Chickpea reviewed research progress during the last two years in Bangladesh, India, and Nepal. This publication contains summaries of the findings and recommendations made for future research priorities. Field experiments conducted in Bangladesh, Nepal, and India suggested that an integrated disease management program if practised along with other improved agronomical practices, can substantially reduce disease severity in chickpea fields and increase chickpea production in disease-prone areas. High priority was given to participatory on-farm validation of the available components of BGM management such as moderate levels of host plant resistance, agronomic options (spaced planting and judicious use of fungicide), and their integration.

The research activities were supported by the Government of Iran and several donors who provide unrestricted support to ICRISAT.

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Summary Proceedings of the Fourth Working Group Meeting to Discuss Collaborative Research on Botrytis Gray Mold of Chickpea

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Joydebpur, Gazipur, Bangladesh

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Introduction

M A Bakr[1] and S Pande[2]

On a global basis chickpea *(Cicer arietinum* L.) is the third most important grain legume crop. It is widely grown and consumed in South Asia and West Asia. Although used mainly as a *dhal* (split pea) in South Asia it is of increasing importance as a sweet or savory snack. As chickpea flour is fine and cooks quickly, there is much scope for ready-to-eat snacks using chickpea flour either alone or in combination with cereal. Demand and prices for chickpea are generally increasing but farmers face many problems in cultivating chickpea successfully, among which the occurrence of diseases is very important. Of the various diseases botrytis gray mold *(Botrytis cinerea* Pers. ex Fr.) (BGM) is important in Bangladesh, Nepal, and in the submontane regions of Bihar and Uttar Pradesh in India. The disease becomes serious following frequent winter rains that result in excessive vegetative growth and high humidity: these conditions favor its infection, epidemic, and severity. Botrytis gray mold is next to ascochyta blight *(Ascochyta rabiei* [Pass] Labor.) in order of worldwide importance of chickpea diseases.

To address the serious impact of BGM, scientists from national agricultural research systems (NARS) of countries where the disease is important, and ICRISAT formed a working group. The group activities were initially coordinated from ICRISAT, with scientists from NARS, ICRISAT, and advanced research institutes being involved in joint activities.

In searching for sources of resistance many accessions were screened both in the field at hot-spot locations and in controlled environment conditions. At Ishurdi, Bangladesh, an excellent facility for screening by using a mist spray-irrigation system was created through cooperation of the national program with the Canadian International Development Agency (CIDA). Large numbers of germplasm and breeding lines have been screened effectively under artificial epiphytotic conditions. High degrees of resistance could not be identified. However, a genotype with an open canopy and upright plant growth habit, ICCL 87322, showed good performance in escaping or tolerating the disease. Apart from the cultivated species, sources of resistance were also sought from among the wild relatives of *Cicer* species. At Punjab Agricultural University (PAU), Ludhiana, Punjab, India, 16 accessions belonging to four wild species,

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namely *C. judaicum, C. bijugum, C. pinnatifidum,* and *C. echinospermum* were identified as having a higher level of resistance to BGM and also ascochyta blight. Subsequent effort will be required for transferring resistance to cultivated species.

Management of the disease by employing different options such as using available levels of resistance, cultural, chemical, and biological agents were investigated in the working group countries. Several options appeared encouraging in on-station trials. Integrating these options in on-farm trials is being planned, to determine the extent to which it is feasible to manage the disease in farmers' field studies.

Inaugural Address

M A Malek[1]

Drs C Johansen, S D Singh, and S Pande from ICRISAT, Dr K B Singh (FAO), Dr D P Singh, Asian Vegetable Research and Development Center (AVRDC), colleagues from India and Nepal, and participants from Bangladesh, I am glad to welcome you to this auspicious Fourth Meeting of the Botrytis Gray Mold of Chickpea (BGM) Working Group for Asia being held at the Bangladesh Agricultural Research Institute (BARI). Undoubtedly, you are aware that BGM is a high priority disease of chickpea in this region, causing severe yield reduction of the crop. The disease therefore warrants immediate remedial measures. Scientists from ICRISAT and concerned NARS have formed a working group to address this problem. I am happy to mention that the first meeting of the working group was also hosted by Bangladesh, in March 1991. The meeting felt the necessity of networking the research to address the chickpea BGM problem. Thus, the working group has been functioning for the last seven years. The recent steering committee meeting of the country coordinators of CLAN held in Indonesia appointed Dr M A Bakr of BARI as the Technical Coordinator of the Botrytis Gray Mold of Chickpea Working Group for Asia. The present activities are being undertaken by the new coordinator. We would like to congratulate Dr Bakr for assuming this responsibility and wish him well in this role. At the third meeting of the working group held at Pantnagar, India, it was decided that the next meeting should be held at BARI, Bangladesh. I am glad to see that the meeting is being organized in a timely and thorough manner. I hope the meeting will discuss the progress of the group activities and formulate future plans of action. As the Country Coordinator of CLAN, I assure you of full cooperation during the meeting and afterwards. I wish you every success for the meeting and hope that the group will proceed towards achieving its goal. Once again I welcome you, hope you have a happy and comfortable stay in Bangladesh, and wish you a successful meeting of the working group.

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Objectives of the Meeting

M A Bakr[1]

Mr Chairman and participants, I welcome all of you to the Fourth Meeting of the Botrytis Gray Mold (BGM) of Chickpea Working Group for Asia. You are quite aware of the grave situation BGM poses to chickpea in this region. There are reports that the disease even causes 100% yield loss in Bangladesh. Similar extents of damage have been reported from the *Tal* areas of northern and north-eastern India. Considerable yield losses (~100%) were reported from the Tarai regions of Nepal. Prevalence of the disease has also been reported from Pakistan and Myanmar. To address this regional problem the working group was formed. I congratulate our colleagues from ICRISAT who were instrumental in organizing the working group activities initially. By now the group has made considerable progress. However, the recent downsizing and restructuring of the ICRISAT program has made it necessary to nominate another coordinator for this Group. This is the first time that a coordinator of this group is from NARS. We are pleased that, in this case, a representative of NARS has been nominated as coordinator; myself. So, as coordinator, I feel it is necessary to discuss several points for better coordination and smooth running of the group activities. The objectives of the meeting are therefore:

- To compile the research activities done under this working group over the previous two years.
- To make an assessment of the progress made after the previous meeting and thereby redefine the recommendations of the third working group meeting.
- To exchange views and ideas regarding research strategy for achieving continued progress.
- To strengthen networking of research on BGM and accelerate working group activities.
- To identify human and fiscal resources available within and outside this group for conducting priority research.
- To share the research activities on BGM being done in Bangladesh with fellow scientists from India, Nepal, and ICRISAT.
- To more closely examine the problem of BGM of chickpea in farmers' field conditions.
- To obtain the views of farmers regarding BGM of chickpea.

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- To establish an agreed workplan for the research agenda based on the available information and resources.

The group meeting will also undertake a field trip to major chick-pea growing areas in Bangladesh e.g. Faridpur, Jessore, and Ishurdi. The participants will interact with chickpea farmers, interview them, and discuss their perceptions of BGM of chickpea.

Additionally, the group will observe research activities being conducted at the Regional Agricultural Research Station (RARS), Jessore, and Pulses Research Center (PRC), Ishurdi. Finally, we will assemble for a wrap-up discussion on deliberations of the three days where the workplan will be refined.

Status of Botrytis Gray Mold of Chickpea Research in Punjab, India

G Singh, Y R Sharma, and T S Bains[1]

Abstract

Botrytis gray mold is one of the most important diseases of chickpea in northwestern India. Development of resistance is an effective method of managing the disease. However, higher levels of resistance to BGM are not available in the cultivated *Cicer* species. Therefore, attempts have been made to identify resistance to BGM in wild species of *Cicer. A* large number of wild species of chickpea were screened in greenhouse conditions following "growth room" and "cut twig" methods. Resistance to BGM has been identified in wild species namely C. *judaicum,* C. *bijugum* and *C. echinospermum.* These species were used in breeding for resistance to BGM and a large number of progenies in different generations are available for multilocational testing. Additionally, newly developed fungicides were also evaluated to control BGM.

Introduction

Botrytis gray mold (BGM) of chickpea caused by *Botrytis cinerea* Pers. ex Fr. is a serious disease in India and South Asian countries. Its first epidemic along with ascochyta blight (AB) was recorded in India in 1980-83. Since then it has been appearing every year in variable intensities depending upon the environmental conditions. This paper presents available information from studies conducted during 1994/95 to 1996/97 at the Punjab Agricultural University (PAU), Ludhiana, on host-plant resistance and management of the disease.

Host-Plant Resistance

Screening techniques. A growth room screening technique is being used at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and

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PAU to screen germplasm and advanced breeding lines. Similarly, to screen germplasm and breeding lines in different segregating generations, a field screening technique is in use at Govind Ballab Pant University of Agriculture and Technology (GBPUA&T), Pantnagar, and the Regional Agricultural Research Station, (RARS), Ishurdi, Bangladesh. High levels of resistance to BGM are not available in cultivated chickpea varieties *(Cicer arietinum* L.), however, they are available in some wild *Cicer* species. Therefore, a cut twig method has been developed at PAU, particularly for wide hybridization programs. This technique proved to be reliable and efficient for screening breeding materials derived from such programs, particularly from back crossing.

The cut twig technique consists of cutting 10-15 cm long tender terminal shoots of chickpea plants with a sharp razor or blade in the evening. The lower portion of twig is wrapped with a cotton plug and transferred to a test tube (15 x 100 mm) containing fresh water. The test tubes containing twigs are placed in a test tube stand and inoculated by spraying a spore suspension with 50 000 spores mL^{-1} of 10-day-old culture of *B. cinerea.* Twigs of chickpea variety G 543 are used as susceptible controls. The inoculated twigs are immediately covered with moist polythene chambers supported by iron frames (46 cm x 46 cm) to provide a leaf wetness period of 144 h. During this period, a daily 8 h light and 16 h dark period is provided. The disease symptoms start appearing 24 h after inoculation. Complete mortality occurs in susceptible lines and the control after 6 days of inoculation. The disease observations are recorded after 6 days of inoculation on a 1-9 point rating scale, where 1 = no disease and 9 = > 75% plants killed by BGM infection. The results of this screening technique are comparable with those of the growth room screening technique.

Wide Hybridization

As a higher level of resistance to BGM in cultivated varieties and germplasm of chickpea is not available, PAU scientists have been searching for resistance in wild *Cicer* species. *Cicer judaicum* 182 and *C. pinnatifidum* 188 had higher levels of resistance to BGM than cultivated chickpea during the epidemic years of 1980-82 (Singh et al. 1982). Later, 16 accessions of eight wild *Cicer* species were screened for resistance to BGM in a growth room. Accessions of *Cicer judaicum, C. bijugum,* and *C. echinospermum* showed considerable resistance to BGM. Incidentally, all of these lines also had higher degrees of resistance to AB (Table 1).

At PAU and ICARDA crosses were made with some of these wild *Cicer* species, such as *C. pinnatifidum, C. judaicum,* and *C. bijugum.* The breeding materials derived from these crosses are in various stages of testing from F2 to F5, BC1, BC2, and BC3. Chickpea lines GL 92162, GL 92165, and GLK 96239 are being tested in yield trials. Several lines are in preliminary trials at PAU. A list of

Table 1. Reaction of wild *Cicer* species to botrytis gray mold (BGM) and ascochyta blight (AB), in a greenhouse screening[1] at PAU, Ludhiana, Punjab, India, 1992-1997 seasons.

Wild *Cicer* species/accessions	Source	Disease rating[2]	
		BGM	AB
Cicer judaicum 182	ICRISAT	3.0	2.0
C. *judaicum* ILWC 19-2	ICARDA	1.5	3.5
C. *pinnatifidum* 188	ICRISAT	1.5	2.0
C. *pinnatifidum* 189	ICRISAT	2.0	2.0
C. *pinnatifidum* 199	ICRISAT	3.0	2.0
C. *pinnatifidum* ILWC 9/S-1	ICARDA	2.0	2.0
C. bijugum ILWC 7/S-1	ICARDA	2.0	3.0
C. *echinospermum* ILWC 35/S-1	ICARDA	1.0	1.0
C. *echinospermum* ILWC 39	ICARDA	2.0	3.0

1. Growth room.
2. Botrytis gray mold and ascochyta blight were scored on 1-9 rating scale, where 1= no disease and 9 = > 75% plants killed.

other chickpea lines derived from the wide hybridization and their resistant parents is given in Table 2. A total of 837 progenies were derived from the wide hybridization crosses of BG 256 x C. *judaicum* 182 (329), BG 256 x C. *echinospermum* 204 (110), L 550 x C. *pinnatifidum* 188 (157), BG 256 x C. *pinnatifidum* 188 (42), and GLK 88012 x C. *pinnatifidum* 188 (199). These progenies were further tested for BGM and AB.

Intraspecific Hybridization

From 1980 to 1997 a total of 10 506 chickpea germplasm and advanced breeding lines were screened in the growth room for resistance to BGM. During this period, several lines having a BGM rating ranging from 3.0 to 5.0 were identified and extensively used in the breeding program. Advanced breeding lines were tested for resistance to BGM at PAU, whereas breeding material in various segregating generations was screened under field conditions at GBPUA&T, Pantnagar, and RARS, Ishurdi, in Bangladesh (Bakr et al. 1997).

During 1994/95 and 1996/97, 1715 germplasm and advanced breeding lines from breeding trials such as SS Trial (SST), Advanced Yield Trial (AYT), and Field Yield Trial (FYT) were tested for resistance to BGM under controlled conditions in the growth room at PAU. Similarly, other research centers in India including GBPUA&T and ICRISAT have also tested chickpea lines for resistance to BGM (Rathi and Tripathi 1993). Of the 1715 lines screened, 16 lines were found to be

Table 2. Botrytis gray mold (BGM) scores of chickpea accessions (including wild *Cicer* spp) and lines derived through wide hydridization and intraspecific crosses at PAU, Ludhiana, 1980-83 seasons[1].

Resistant parent	BGM rating[2]	Entry	BGM rating
		Wide hybridization	
		GL 92162	4.0
C. *pinnatifidum* 188	1.5	GL 92165	4.0
C. *echinospermum* 204	6.0	GLK 96239	5.0
C. *judaicum* 182	3.0		
		Intraspecific hybridization	
		GL 84060	5.0
Negro	4.0	GL 84107	4.0
E 100Y	3.0		
P 1528-1-1		GL 84108	4.0
E 100Y	3.0		
P 1528-1-1		GL 84133	3.0
P 1528-1-1	4.0	GL 84295	4.5
P 1528-1-1	4.0	GL 88358	4.5
C 8	4.0	GL 91040	3.0
E 100Y	3.0	GL 85103	4.0
P 1528-1-1	4.0	—	

1. Under field conditions in epidemic years 1980-83.
2. BGM was scored on 1-9 scale, where 1= no disease, and 9 = > 75% plants killed.

resistant (4-4.5 rating), while 22 lines were identified as moderately resistant (~5 rating) to BGM (Table 3). In Bangladesh ICCX 860732-BP-BH-BH-1H-BH had a BGM rating of 4.0 and ICCX 860444-BP-5PN-BPN-2H-BH a rating of 5.0 (Bakr et al. 1997).

Enhancement of BGM Resistance

From 1980-81 onwards this center has been trying to identify sources of resistance to BGM which invariably had a rating of 5.0 and then tried to incorporate this resistance through breeding methods. Some of the breeding lines tested over two or three years that showed a BGM rating between 3.0 and 5.0 are

Table 3. Rating scores of the lines most resistant to BGM from 1715 chickpea lines tested in a growth room at PAU, Ludhiana, during 1994-97.

BGM score[1]	No. of lines	Chickpea lines
4.0	8	GL 90178, GL 92162, GL 92165, FG 575, FG 576,GN G737,BDG 74,GICG 92228
4.5	4	ICCX 860007-14PN-BPNBPN-BPN, ICCX 860009-B-BH-2PN-BPN-BPN-BPN, ICCX 860732-BP-BH-BH-BH-1H-2BH, ICCX 870207-BP-BH-4H-BH
5.0	24	GL 84041, GL 90236, GL 90270, GL 94022, GL 94046,GL 94087, GL 94088, GL 94098, GLK 96239, FG 559, FG 579, FG 580, FG 581, FG 596, FG 601, FG 729, SAKI 93-130, PGK 502, ICCX 800837, ICCX 860418-BP-BH-5H-BH, ICCX 860444-BP-5PN-BPN-2H-BH, ICCX 860510-BP-2H-BP, ICCX 880354-BU-BP-51H-BP-BH, ICCX 880355-BH-BP-5H-BH

1. BGM score on 1-9 rating, when 1 = no disease and 9 = > 75% plants killed.

Table 4. Chickpea lines showing consistency to BGM reaction over two to three years of testing.

	BGM Rating[2]			
Genotype[1]	1st year	2nd year	3rd year	Mean
GL 84060	5.0	5.0	-	5.0
GL 84094	3.0	-	5.0	4.0
GL 84107	5.0	3.0	-	4.0
GL 84108	5.0	3.0	-	4.0
GL 84133	3.0	3.0	-	3.0
GL 84212	5.0	2.0	5.0	4.0
GL 84295	-	4.0	5.0	4.5
GL 86094	5.0	3.0	-	4.0
GL 88358	4.0	5.0	-	4.5
GL 88372	4.0	5.0	-	4.5

1. All these lines were also resistant to AB.
2. BGM rating of 1-9 scale, where 1 = no disease, and 9 = > 75% plants killed.

given in Table 4. This trend was more clearly reflected in an earlier communication of Singh et al. (1997) in which they reported five lines i.e., PGL 700, GL 90159, GL 91040, KPG 70, and BG 439 scored 3.0 and another 13 lines rated 4.0. These lines need to be tested at several locations and against various races or pathotypes in order to confirm their stability for resistance to BGM.

Chemical Control

To control foliar infection of BGM, six fungicides, Bavistin® (carbendazim), Balyeton® (triadimefon), Belltone®, Captaf®, Dithane M-45® (mancozeb), and Kavach® (chlorothalonil) were tested during 1994/95. Four new fungicides, Baycor® (bitectans), Celest®, Chlorothalonil 40SC, and Cyperconazole 50SC were also evaluated in 1995/96. All these fungicides were tested again during the 1997/98 postrainy season. These studies indicated that all the fungicides were very effective in controlling the foliar infection (Table 5).

Table 5. Comparative efficacy of fungicides to control foliar infection of BGM, in two years of evaluation, at PAU, Ludhiana, India.

Fungicide/year	Dose (g ha^{-1})	BGM score[1]
Year 1994/95		
Bavistin®	890	3.3
Bayleton®	495	3.1
Belltone®	495	3.3
Captaf®	1185	3.0
Dithane M-45®	890	2.9
Kavach®	890	3.4
Control	-	7.8
LSD at 5%		0.38
Year 1995/96		
Baycor®	495	1.7
Celest®	860	1.5
Chlorothalonil 40SC	860	1.7
Cyperconazole 50SC	860	2.6
Kavach®	860	1.4
Captaf®	860	1.0
Control	-	7.1
LSD at 5%		2.9

1. BGM score on 1-9 rating scale, where 1 = no disease, and 9 = > 75% plants killed.

In a previous study Singh and Bhan (1986) reported that the treatment of seed with any of the fungicides, Bavistin® +Thiram® (1:1), Dithane M-45®, Bavistin® 3g, thiabendazole 2g, Ronilan® (vinclozin) and Rovral® (iprodione) 4g kg^{-1} of seed, almost eliminated the seedborne infection. Application of Dithane M-45® 860 g, thiabendazole 495 g, Baytan® (triadimenol) 495 g, Bayleton® 495 g and Thiram® 860 g ha^{-1} in 100 L of water immediately after rain during crop growth, particularly during February - March, almost completely controlled the foliar infection (Singh et al. 1997). Bavistin® and Ronilan® were found very effective for the control of foliar infection at Pantnagar (Rathi and Tripathi 1993).

Conclusion

Higher levels of resistance to BGM were identified in wild *Cicer* species and utilized in the genetic enhancement to BGM following the backcross method of breeding. The breeding lines derived from the crosses involving wild species of *Cicer* are in various stages of evaluation and some of them have been found resistant to AB disease of chickpea also. For effective use of wild species concerted efforts and cooperation are needed among the BGM working group countries and ICRISAT especially for testing of interspecific derivatives across different environments.

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Steps Towards Management of Botrytis Gray Mold of Chickpea in Bangladesh

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Abstract

The search for host-plant resistance to BGM, and its evaluation both in controlled and field conditions were continued. To devise an integrated management package to minimize the losses caused by BGM, experiments including agronomic practices, host-plant resistance, and judicious use of fungicides were conducted. A chickpea line with an erect growth habit, ICCL 87322, which was found resistant to BGM, was evaluated multilocationally at major chickpea growing areas in Bangladesh.

Introduction

Botrytis gray mold (BGM) is one of the most important diseases of chickpea *(Cicer arietinum* L.) in Bangladesh. The disease is also serious in parts of India and Nepal. Research is carried out under the umbrella of the Botrytis Gray Mold (BGM) of Chickpea Working Group for Asia. This paper reports the results of research conducted during two consecutive seasons, 1995/96 and 1996/97.

Search for Resistant Sources

Field screening of chickpea genotypes under field conditions for resistance to BGM was initiated in the 1990/91 cropping season at the Bangladesh Agricultural Research Institute (BARI), Ishurdi. Later, efforts were extended to the Regional Agricultural Research Station (RARS), Jessore, where disease pressure was more severe. Mist irrigation facilities were developed at Ishurdi to provide a congenial environment for disease development and effective screening. Since the 1993/94 cropping season this system has been used effectively in an area of 0.4 ha. The observation nursery for BGM sent from ICRISAT was also sown at Ishurdi under the mist irrigation system. There were 30 entries in this nursery.

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Bakr, M.A., Rahman, M.L, Hossain, M.S., and Ahmed, A.U. 1996. Steps towards management of botrytis gray mold of chickpea in Bangladesh. Pages 15-18 *in* Recent advances in research and management of botrytis gray mold of chickpea: summary proceedings of the Fourth Working Group Meeting to Discuss Collaborative Research on Botrytis Gray Mold of Chickpea, 23-26 Feb 1998, BARI, Joydebpur, Gazipur 1701, Bangladesh (Pande, S., Bakr, M. A., and Johansen, C., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Each entry was sown in a single row plot of 5 m length with row-to-row distance of 40 cm. The trial had three replications. The susceptible control (ICC 4954) was planted after every test entry row. Mist irrigation was applied four times a day, for twenty minutes each time at two hourly intervals. The mist irrigation system was started at 50% of flowering of the crop and continued until it neared maturity. The disease was scored at 10-day intervals using a 1-9 rating scale, where 1 = no disease and no mortality and 9 = > 75% plants killed. The performance of the entries was decided over the mean of three replications.

Nine entries were selected as tolerant to BGM, scoring 5-6 on the 1-9 scale but none was found to be resistant (4 or less).

An observation nursery was also sown at Ishurdi consisting of 25 entries. This nursery was evaluated for BGM resistance under the mist irrigation system. The BGM score ranged between 5 and 7 and most of the entries were susceptible to BGM.

BGM Management by Plant Resistance, and Agronomic and Chemical Approaches

Different options were tried for the management of BGM. One was to space the chickpea plants and reduce the favorable microclimate for BGM development. The following treatment combinations integrated different components (spacing, intercropping, host-plant resistance, and judicious use of fungicide) for BGM management: (1) spacing: 30x10 cm vs. 60:40:60 cm paired row, (2) intercropping: sole vs. intercropped with linseed, (3) host-plant resistance: genotype ICCL 87322 vs. Pant G 114 and, (4) spraying fungicide vs. no spraying of fungicide.

The plant spacing of 60:40:60 cm in paired rows produced a higher yield and showed lower disease incidence than 30x10 cm conventional spacing. Chickpea genotype ICCL 87322, when intercropped with linseed, produced a higher yield than that in sole-cropped conditions. Between the two varieties evaluated, ICCL 87322 was superior and had less severe disease and higher grain yield than Pant G 114. Spraying with Bavistin® lowered BGM disease severity appreciably, compared with no spraying. These studies concluded that the disease can be managed by the adoption of these approaches individually to some extent and in combination with a greater degree of efficacy. These on-station studies suggest that integrating wider spacing (60:40:60 cm) with genotype ICCL 87322 as a solecrop or intercropped, and a minimal spray of fungicide (once or twice) can be practised for the integrated management of BGM of chickpea (Table 1).

Similar studies were also conducted at Joydebpur where farmers' practices were compared with the improved practices. The improved practices included spraying of fungicide (Bavistin®) two times at an interval of 14 days and sowing of a tolerant genotype, ICCL 87322, at the usual time (10-25 Nov) in normal spac-

Table 1. Comparison of improved practices with farmers' practices in disease management of botrytis gray mold.

Treatments	BGM score[1] (1-9 scale)	Seed yield (kg ha^1)
Normal date of sowing of susceptible genotype Pant G 114 or Nabin with farmers' spacing 30 x 10 cm	4.25b	412.5 b
Tolerant genotype (ICCL 87322) in spacing 60:40:60 cm	2.25 d	650.0 a
Tolerant genotype with spray of Bavistin®	3.25 c	637.5 a
Tolerant genotype with linseed intercropping	3.50 c	612.0 a
Late sown (15 days later than normal) susceptible genotype (Pant G 114 or Nabin) intercropped with linseed	4.75 b	375.0 b
Susceptible genotype sole crop late sown by broadcasting	5.75 a	287.5 c

1. Where 1 = no disease; 9 = > 75% diseased or dead.
2. Within columns, numbers followed by the same letter are not significantly different at $P = 0.05$.

ing (40x10 cm), while the farmers' practices were no spraying of fungicide, sowing 15 days later than the normal date, and using susceptible genotype, Nabin, at a wider spacing (40 x 20 cm).

The tolerant genotype ICCL 87322, with normal spacing, produced the highest yield. Also the grain yield of the same cultivar did not differ significantly when protected with fungicide. But in the late-sown trial the tolerant genotype crop produced significantly lower yields than when sown at a normal time. In the normal sowing chickpea variety Nabin produced grain yields similar to yields of the late-sown tolerant genotype.

The tolerant cultivar when sown at the normal time was least infected with BGM. Maximum disease severities were recorded in the late-sown Nabin variety when intercropped with linseed.

Multilocational Demonstrations of BGM Resistance in Chickpea

Chickpea line ICCL 87322 was selected as a genotype tolerant to BGM. This genotype has characters such as an open canopy with an upright branching habit and resistance to soilborne diseases (wilt and collar rot). It was, therefore, decided to test its suitability at various locations such as Jessore, Joydebpur, and

Table *2.* Performance of selected chickpea entries scored for botrytis gray mold in multilocational screening, Bangladesh.

	Ishurdi		Jessore		Joydebpur	
Entries	Disease score[1] (1-9)	Grain yield (kg ha^{1})	Disease score (1-9)	Grain yield (kg ha^{1})	Disease score (1-9)	Grain yield (kg ha^{1})
ICCL 87322	6.0	978	3.0	987	3.0	1375
H 208 (control)	9.0	310	9.0	513	7.0	650

1. On a scale where 1 = no disease; 9 = > 75% diseased or dead.

Ishurdi. The results given in Table 2 show that ICCL 87332 has the potential to tolerate BGM infection and development and is a suitable candidate to be included in the on-farm evaluation of BGM management options.

Seed to Plant Transmission of BGM

This aspect of BGM etiology was thoroughly discussed in the third BGM working group meeting held at Pantnagar, India. Accordingly, a study was initiated at Joydebpur to determine whether the seedborne inoculum of BGM is carried over and transmitted to initiate infection of the crop in the next generation. Seed samples of chickpea were collected from Ishurdi and Jessore where the crop was severely infected with BGM and samples analysed for infection. A subsample of the seeds was sown in sterilized soil in earthen pots of 20 cm top diameter. There was no infection of BGM in seedlings or on older plants up to plant maturity.

Conclusion

Botrytis gray mold of chickpea is strongly influenced by the environment. Chickpea cultivars with high levels of resistance to BGM are not available. The field trials conducted in Bangladesh indicated that BGM in chickpea can be managed effectively by sowing an erect, tall, and moderately resistant genotype (ICCL 87322) at wide spacing with need-based minimum use of fungicide. At present these components, along with manipulation of sowing dates, are being developed into a management strategy for transfer to farmers.

Progress of Research on Botrytis Gray Mold of Chickpea in Nepal, 1995-97

P C P Chaurasia[1]

Abstract

Twenty-one chickpea lines were screened in the BGM nursery at Rampur and newly established nursery at Tarahara during the 1996/97 season. Disease pressure was equally high at both the locations and most of the lines were susceptible to BGM except chickpea line ICCX 840508-33. This line was moderately resistant to BGM at both these locations. Also a biocontrol agent *(Trichoderma viride)* was compared with fungicide (Ronilan®) to control BGM. These studies indicated that three sprays with the biocontrol agent were most effective in reducing the disease.

Introduction

Botrytis gray mold (BGM), caused by *Botrytis cinerea* Pers. ex Fr., is one of the most important fungal diseases of chickpea. In Nepal it occurs throughout the chickpea growing areas. However, its epidemics are more frequently experienced in the central and eastern Tarai, where environmental conditions are more favorable for disease development in comparison with those in other parts of the Tarai. Different aspects of disease management have been worked out in collaboration with ICRISAT since the establishment of the National Grain Legumes Research Program (GLRP) at Rampur, Chitwan. Work done on the management of BGM of chickpea in Nepal for the last two years is summarized.

Screening of Breeding Materials and Other Genotypes

A BGM observation nursery including 30 lines was screened at GLRP, Rampur, Chitwan, and the Regional Agricultural Research Station (RARS), Tarahara, during the 1996/97 cropping season. Test entries were planted in 5 m rows, with a row of a susceptible control entry (ICC 4954) after every two test entries. The

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entries were sown in two replications. The disease severity was rated on 1-9 rating scale. During 1996/97, the natural occurrence of the disease was very low. Therefore, the screening was repeated during the 1997/98 crop season and results are awaited. Additionally, a set of 20 lines was sown at Parwanipur and Tarahara during the 1995/96 season. Disease pressure was greater at Tarahara than at Parwanipur (Table 1). Most of the entries at Tarahara scored between 7 and 9 except the entry ICCX 840508-33 which scored 5 at both locations.

Table 1. Reactions of chickpea genotypes to botrytis gray mold at Parwanipur and Tarahara, Nepal, in the 1995/96 season.

	Disease score[1]	
Genotypes	Parwanipur	Tarahara
ICCX 860443-BP-17PN-1H-BH	7	8
ICCX 860444-BP-5PN-BPN-2H-BH	7	9
ICCX 860677-BP-BH-1H-BH	8	9
ICCX 860732-BP-BH-BH-1H-BH	6	7
ICCX 870207-BP-BH-4H-BH	5	9
ICCX 870207-BP-BH-11H-BH	7	7
ICCX 840504-4H-BH-1H-BH	6	7
ICCX 860510-BP-2H-BH	7	9
ICCL 83103	5	8
ICCL 83105	7	7
ICCL 87322	7	7
ICCV 88510	7	9
ICCV 92501	5	7
ICCV 93928	7	9
ICCV 840508-6	5	7
ICCX 840508-26	6	9
ICCX 840508-31	7	7
ICCX 840508-32	5	7
ICCX 840508-33	5	5
ICCX 840508-36	5	7
ICC 4954 (control)	9	7

1. Disease score on 1-9 rating scale, where 1 = no disease and plant mortality and 9 = > 75% plants diseased or dead.

Biological and Chemical Control Approaches

A set of fungicides was evaluated along with biological control agents to be included in the integrated management of BGM. A collaborative study involving ICRISAT was conducted at GLRP, Rampur, during 1995/96 and at RARS, Tarahara, during 1996/97 using chickpea cultivar Sita. The study had six treatments: (1) three sprays of *Trichoderma viride* (10^7 - 10^{10} spores mL^{-1}), (2) two sprays of T. viride, (3) three sprays of Ronilari® or Bavistin®, (4) two sprays of Ronilan®, (5) three sprays of T. *viride* + Ronilan®, and (6) control (water spray).

No significant differences were observed among the different treatment combinations. However, three sprays of Ronilan® gave the best results in reducing the disease severity (as measured by the area under disease progress curve: AUDPC) followed by the three sprays of *T. viride* and Ronilan® (Table 2).

Table 2. Effect of *T. viride* and Ronilan® on flower drop, area under disease progress curve (AUDPC), and grain yield of chickpea.

	Rampur, Chitwan 1996			RARS, Tarahara 1997		
Treatment	Flower drop (%)	AUDPC	Grain yield (t ha^{-1})	Flower drop (%)	AUDPC	Grain yield (t ha^{-1})
Control	17.6	631.0	0.39	43.6	2.0	1.3
Two sprays of *T. viride* (10^7-10^{10} spores mL^{-1})	18.3	370.5	0.42	31.0	1.1	1.2
Three sprays of *T. viride*	20.6	503.0	0.35	37.7	2.0	1.4
Two sprays of Ronilan® (0.1%)	24.3	402.5	0.37	39.3	1.15	1.2
Three sprays of Ronilan®	16.6	303.6	0.38	35.9	2.2	1.2
Three sprays of *T. viride* + Ronilan®	14.6	376.3	0.42	37.5	2.0	1.2
LSD (P=0.05)	NS	NS		NS	NS	

Conclusions

BGM research activities have begun at Tarahara in eastern Nepal, where environmental conditions for disease development are more favorable than Rampur. Last year's data on BGM incidence and severity indicated the importance of selecting Tarhara as the key location for BGM resistance screening. All the test entries were found to be highly susceptible to BGM. High priority will be given to establishing a BGM screening nursery and conducting experiments on the management of the disease.

Management of Botrytis Gray Mold of Chickpea - A Review

S Pande, C Johansen, and J Narayana Rao[1]

Abstract

Botrytis gray mold (BGM) caused by *Botrytis cinerea* is an important foliar disease of chickpea. Its origin and distribution, losses caused by BGM, symptoms, causal organism and its variability, epidemiology, and host range are briefly reviewed. Attempts have also been made to assemble the information on integrated disease management (IDM) of BGM. The IDM components reviewed were: (1) host-plant resistance, (2) agronomic and cultural practices including effects of sowing date (escape), row spacing, plant type, and intercropping, (3) management by chemicals which include seed treatment and foliar sprays, and (4) management with biological agents. Integrated BGM management in chickpea involves use of BGM-resistant cultivars with improved agronomic and cultural practices including economical use of fungicides, but these practices are not yet sufficiently refined to be adapted by resource-poor farmers in Asia (specifically in Nepal, Bangladesh, and India). Therefore, farmers participatory on-farm research is needed to devise appropriate packages of these strategies for BGM endemic areas.

Introduction

Botrytis gray mold (BGM), caused by *Botrytis cinerea* Pers. ex Fr., is an important fungal foliar disease of chickpea *(Cicer arietinum* L.*)* in India, Bangladesh, Nepal, and Pakistan. The disease has also been reported as a major yield reducer in Australia and Argentina. It causes severe damage to-the crop, if the conditions are favorable during the vegetative and reproductive growth stages, and can cause substantial yield losses (Grewal and Laha 1983). Substantial and stable sources of host plants resistant (genetic resistance) to BGM are not available in

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the germplasm and breeding material (Laha and Khatua 1988, Ahmad 1989, Singh et al. 1992). However, high levels of resistance to BGM have been reported in wild *Cicer* spp (Singh et al. 1992, Haware et al. 1992). Several seed dressing and foliar fungicides have been found effective (Grewal and Laha 1983, Singh and Bhan 1986b, Singh and Kaur 1990) but the use of fungicides to manage the disease has not been widely adopted by resource-poor farmers (Singh and Bhan 1986b). Hence, integrated disease management of BGM using available levels of host resistance, improved agronomical practices, more dependence on biological agents (if available), and targeted spraying with effective fungicides is being advocated.

Economic Losses

There are several reports of serious losses caused by BGM. Carranza (1965) reported a 95% crop loss in Jujuy province of Argentina due to BGM. The disease was responsible for heavy losses in the Indo-Gangetic plains of India during 1979-82 (Grewal and Laha 1983). During 1979 the disease appeared in epiphytotic form and destroyed chickpea crops completely over an area of 2000 ha in India (Chaube et al. 1992). In Bangladesh, the damage caused by the disease was estimated to be 80-90% in 1988 and 70-80% in 1989 (Bakr and Ahmed 1992). In Nepal the disease occurs almost every year and an estimated loss of 66% in the experimental fields and about 15% in farmers' fields was reported (Joshi 1992). Recently more than 80% crop losses due to BGM have been observed in Bangladesh, Nepal, and north-western India (S Pande, ICRISAT, personal communication, 1998).

Origin and Geographical Distribution

The occurrence of BGM on chickpea was first reported by Shaw and Ajrekar in 1915, but Carranza (1965) reported its first field incidence from Argentina. The disease has been reported from Argentina, Australia, Bangladesh, Canada, Colombia, India, Myanmar, Nepal, Pakistan, Spain, Turkey, and USA (Malik et al. 1993, Nene et al. 1984, Haware and McDonald 1993).

Pathogen

The causal organism of BGM of chickpea is *Botrytis cinerea* Pers. ex Fr. The perfect stage of the fungus is *Sclerotinia fuckeliana* (Groves and Loveland 1953). However, there is no report of the occurrence of the perfect stage on chickpea.

The fungal mycelium is septate and brown, and young hyphae are thin, hyaline/and 8 to 16µ wide. The conidiophores are light brown, septate, erect, and their tips are slightly enlarged bearing small pointed sterigmata. The conidia are hyaline, one-celled, oval or globose, and are borne in clusters on short sterigmata. Conidia from chickpea plants measure 4-25 x 4-18µ (and from potato-dextrose-agar 4-16 x 4-10µ. The sporodochia on the host surface are 0.5-5.0µ in diameter (Joshi and Singh 1969).

Disease Symptoms

Several workers have described the symptoms of BGM as it occurs in different chickpea-growing regions (Joshi and Singh 1969, Kharbanda and Bernier 1979, Haware and Nene 1982). The symptoms are remarkably similar. Under natural conditions, the disease first appears in isolated patches when the crop has reached its maximum vegetative growth stage and high relative humidity (> 95% RH) and temperature (28-30°C) prevail. The symptoms appear on the chickpea stem, leaves, flowers, and pods as gray or dark brown lesions covered with erect hairy sporophores and masses of hyaline spores. Drooping of the affected tender terminal branches is a common field symptom. Stem lesions are 10 to 30 mm long and girdle the stem completely. Affected leaves and flowers turn into a rotting mass. On thick, hard stems, the gray mold is gradually transformed into a dirty gray mass containing dark green to black sporodochia.

When BGM affects pods, no seeds or only small, shrivelled seeds are formed. Sometimes grayish-white mycelia may be seen on immature seeds. Lesions on the pod are water-soaked and irregular, sometimes with black sclerotial bodies scattered in the infected areas.

Variability

There have been very few studies on variability but the pathogen produces different pathotypes or races to cope with host diversity and fluctuating environmental conditions. Joshi and Singh (1969) and Singh (1970) observed formation of sclerotial and/or sporodochial bodies on chickpea plants infected with *B. cinerea* in the Tarai region of Nainital, India. But Pandey (1988) did not observe these bodies in the same location. This indicates that certain isolates of *B. cinerea* are capable of producing sclerotia while others do not and within a location there may be more than one isolate of the fungus. Singh and Bhan (1986a) identified four physiological races from northern India. At present five physiological races of *B. cinerea* have been reported from India alone (Rewal 1987, Rewal and Grewal 1989 b).

Epidemiology

Botrytis cinerea survives in the soil in the form of mycelia and sclerotia from one crop season to the next. The infected plant debris and infested soil are the main sources of primary inoculum (Mahmood and Sinha 1990).

Plant debris. Madhu Meeta et al. (1986b) reported that *B. cinerea* survived in plant debris for 180 days in the soil at a depth of 6 cm. The fungus was found to be viable in infected seed and plant debris stored at 18°C for 5 years (Grewal

1988), but Singh (1989) found that *B. cinerea* did not survive beyond 8 months in chickpea debris at a depth of 10 cm in the soil and he also found that the survival and recovery of the fungus was more at 5-10°C Singh and Tripathi (1993) observed the survival of *B. cinerea* in infected chickpea debris until the following season. It also survived for 8 months at a depth of 25 cm.

Seed. The seedborne nature of *B. cinerea* on chickpea has been reported by many workers (Cother 1977, Laha and Grewal 1983b, Haware et al. 1986, Sandhu and Sah 1988). The fungus remained viable in the infected seed until the next growing season (Madhu Meeta et al. 1986b). Grewal (1988) reported the fungus was externally and internally seedborne. Singh (1989) recorded its survival in chickpea seed for 8 months. He further recorded the survival of this fungus was affected by the ambient temperature prevalent during storage of the seed. Singh and Tripathi (1992) indicated the survival and recovery of the fungus was significantly more at 5-10°C Singh and Tripathi (1993) also reported that the survival period decreased with the increase in storage period and did not survive in the seed at 40°C. Despite the fact that infected seeds carry the inoculum for a considerable period, the role of seedborne inoculum, after coming in contact with the soil environment, in the epidemiology of the disease is not yet established.

Environmental factors. Relative humidity, duration of leaf wetness (Butler 1993), and temperature are the important factors for BGM development. Flow of air can be an influence by modifying humidity and temperature in crop canopies and hence the BGM development depends on the density of the crop canopy Bakr et al. (1993) reported that the incidence of the disease was much higher when the mean temperature ranged from 17 to 28°C and relative humidity from 70 to 97%. Singh and Kapoor (1984) observed that there was an increase in the disease intensity with increase in the leaf wetness period beyond 12 h per day. Rewal and Grewal (1989b) reported that 5°C was the minimum, 20°C the optimum, and 30°C the maximum for conidial germination of all three isolates studied and also that all the three isolates required differential light intensities and relative humidity for conidial germination. The fungus could grow in a wide range of temperatures, but the optimal temperature for fungal growth and sporulation was 25°C (Mahmood and Sinha 1990). A relative humidity of 95% or above for few hours during the day and a dense canopy were most favorable for infection and rapid spread of the disease (Tripathi and Rathi 1992).

Host Range

Botrytis cinerea is a facultative parasite and has a wide host range. Madhu Meeta et al. (1988) reported that *B. cinerea* could infect pea *(Visum sativum)* and several weeds under greenhouse conditions. Rathi and Tripathi (1991) also observed that it could infect 8 cultivated species and 21 weeds. Singh (1997) reported that it could infect about 100 plant species, including ornamental plants, vegetables, fruit crops, field crops, and several weeds.

Host-Plant Resistance

Sowing disease-resistant cultivars is the cheapest and most effective method to combat BGM, but an adequately high level of resistance is not available in germplasm and breeding material of chickpea. Extensive screening (both in controlled environment and at hot-spot locations) of germplasm in India and Nepal indicated that there were no genotypes with a high level of resistance (Haware and Nene 1982, Rathi et al. 1984). Rewal (1987) tested large numbers of chickpea lines for BGM resistance and found ICC 1069 and ICC 5035 to be relatively resistant. Laha and Khatua (1988) also reported that ICC 1069 was most resistant to BGM. Singh and Kaur (1989) reported that GL 84195 and GL 84212 were most resistant and GL 86094 was moderately resistant to BGM. Ahmad (1989) found cultivars only moderately resistant to BGM in his screening in Bihar state of India. Several lines found resistant at Pantnagar were susceptible at Rampur, Nepal (Haware and McDonald 1993). Recently chickpea genotype ICCL 87332, a tall and erect type, has been found to be resistant (BGM score 5) at hot-spot locations in India, (Haware et al. 1997), Bangladesh (M A Bakr, Joydebpur, Bangladesh, personal communication), and Nepal (P C P Chaurasia, Tarhara, Nepal, personal communication). The lines found resistant at one place became susceptible at other places because of the pathogen variability (Singh and Bhan 1986a).

As higher levels of resistance are not available in the cultivated species of *Cicer,* attempts have been made to identify and utilize resistance from the wild *Cicer* species. *Cicer judaicum* 182, *C. judaicum* ILWC 19-2, and *C. pinnatifidum* accessions were highly resistant to BGM (Gurdip Singh, PAU, Ludhiana, India, personal communication).

Integrated Disease Management

Effective management of BGM is very important, or it will cause heavy damage to the chickpea crop. Since a high level of resistance to BGM in the cultivated chickpea is not available, whatever resistance is available needs to be combined with management options that will minimize the disease. Although repeated application of fungicides can control BGM it may not be practicable for resource-poor farmers in the main seasons of chickpea in BGM-endemic areas of South Asia and could result in the production of new and/or resistant strains of the fungus (Bhan and Chatrath 1994). Judicious use of fungicides as a seed treatment and/or foliar spray in an integrated disease management system could be very economical and affordable to the resource-poor farmer. Integrated disease management systems comprising the use of available levels of host-plant resistance, agronomical and cultural, chemical and biological disease control components in total or in several combinations, need to be developed, evaluated, and promoted. A brief review of these components follows.

Agronomic and cultural management. Agronomic and cultural management of BGM in recent years has been very well demonstrated in India, Bangladesh, and Nepal. Early sowings, high seed rates, closer row spacings, and traditional use of bushy genotypes result in dense canopies which favor development of BGM in chickpea. Thus, techniques which minimize canopy density may alleviate disease intensity.

Effect of sowing date. A crop sown after the optimal date of planting often becomes productive and avoids the most vulnerable growth stage and weather conditions favorable for BGM development. Early sowing results in excessive vegetative growth due to more residual moisture and low to moderate temperatures causing more BGM incidence, whereas late sowing checks vegetative growth and hence lowers disease incidence. In both these situations the grain yields were low (Brinsmead 1992, Haware and McDonald 1992). Karki et al. (1989 and 1993) observed that delayed sowings reduced BGM incidence but resulted in low grain yields. Further, they noticed positive correlations between plant height and BGM incidence. Haware and McDonald (1993) reported that delayed sowings reduced BGM incidence even in susceptible cultivars, but the delayed sowings reduced the grain yields. Singh (1997) also observed that the late-sown crop (around 20 Nov) in Punjab, India, showed significantly low incidence of BGM. Bakr et al. (1997) also observed that early-sown crops had more BGM disease both in compact and bushy genotypes than the late-sown crops in Bangladesh. Similar results were also obtained in India by Haware et al. (1997).

Effect of row spacing. Wider spacings between rows reduces BGM incidence. This may be because of more aeration in the crop canopy which results in reduced periods of leaf wetness, to levels below the requirement for disease development. Reddy et al. (1988) observed that wide spacing between rows reduced the RH of the crop canopy and thereby caused a lower incidence of BGM in Nepal. Reddy et al. (1993) observed similar results at Pantnagar, India. Haware and McDonald (1992 and 1993) reported that BGM incidence was lower at wider row spacings than at closer spacings in both fungicide sprayed and nonsprayed plots. Bakr et al. (1993) reported that wide spacing alone reduced BGM disease significantly in Bangladesh. Haware et al. (1997), Bakr et al. (1997), and Shrestha et al. (1997) also reported that wider row spacings reduced BGM disease incidence and obtained more grain yields. These results are presented in Table 1 (Haware et al. 1997).

There are not many studies on the effect of sowing geometry, row spacing, and row orientation, with respect to natural wind direction, and their effects on

Table 1. Effect of row spacing and Ronilan® sprays on the severity of botrytis gray mold, and grain yield in chickpea, Pantnagar, India, 1992/93.

Treatment	Cultivar	Spacing	Disease rating (1-9 scale)	Yield[1] (kg ha^{-1})
Sprayed[2]	ICCL 87322	30 x 10	4.3	1192
		60 x 10	3.3	1291
		45:15:45	4.3	1200
		60:40:60	3.3	1176
	H 208	30 x 10	5.7	1265
		60 x 10	4.7	1139
		45:15:45	4.7	1157
		60:40:60	4.7	1086
Nonsprayed	ICCL 87322	30 x 10	5.7	989
		60 x 10	4.3	989
		45:15:45	4.3	911
		60:40:60	4.0	1044
	H 208	30 x 10	8.0	459
		60 x 10	6.3	349
		45:15:45	6.3	392
		60:40:60	6.0	399
SE				
Cultivars			±0.124*	±85.1
Spacings			±0.175*	±120.4
Sprayings			±0.124*	±85.1*
Spacing x spraying			±0.248	±170.2
Cultivar x spacing			±0.238	±170.2
Cultivar x spraying			±0.175**	±120.4**
Cultivar x spraying x spacing			±0.350	±240.7
CV (%)			12.1	45.4

1. Mean of three replications.
2. Fungicide Ronilan® (0.2%).
* Significant at 1%; **Significant at 5%.

Source: Haware et al. 1997.

leaf wetness and disease incidence. Information on these aspects would be useful to further improve the agronomic management of this disease.

Effect of plant type. Erect and compact growth habit genotypes show lower BGM incidence than bushy and spreading genotypes (Reddy et al. 1988). An erect and compact growth habit provides more aeration to the crop canopy thus changing the microclimate favorable for BGM development. Reddy et al. (1990 and 1993) again observed that tall, erect, and compact genotypes showed less BGM incidence and gave more grain yield in Pantnagar, India. Haware and McDonald (1992 and 1993) also noticed that BGM incidence was much lower in tall, erect, and compact genotypes than bushy and spreading genotypes. Haware et al. (1997) from India, Bakr et al. (1997) from Bangladesh, and Shrestha et al. (1997) from Nepal also observed that tall, erect, and compact growth habit genotypes showed less incidence of BGM than bushy and spreading genotypes. The effect of compact plant type on BGM disease is attributed to the differences in microclimate conditions that this trait could cause. However, no data are available to verify this effect of plant type on microclimate under field conditions.

Effect of intercropping. Little work has been done on the effect of intercropping on BGM development in chickpea. Reddy et al. (1990) reported that when chickpea was intercropped with linseed in Nepal, a marginal increase in chickpea grain yield was obtained because of low BGM disease incidence and the linseed yield was a bonus, but Karki et al. (1993) reported that there was no significant difference in BGM incidence in sole or intercrop with mustard in Nepal. Bakr et al. (1993) observed that chickpea intercropped with linseed showed a reduced incidence of BGM in Bangladesh. These workers also suggested the use of linseed as intercrop in the integrated management of BGM disease of chickpea.

Management by chemicals. *Borytis cinerea,* the causal organism of BGM of chickpea, is presumably internally seedborne. The external seedborne nature of the fungus is also evident (Grewal et al. 1992, Laha and Grewal 1983b). The seedborne nature of this fungus on chickpea has been reported by several workers (Cother 1977, Laha and Grewal 1983b, Haware et al. 1986, Sandhu and Sah 1988). The management of BGM on chickpea with chemicals involves seed treatment or foliar sprays with one or a combination of two of the several fungicides identified to control the disease.

Seed treatment Seed treatment with fungicide protects the crop from seedborne inoculum which could be the primary source of BGM disease development. Seed treatment with a mixture of 25% Bavistin® (carbendazim) and 50% Thiram® at the rate of 0.25% eliminated external and internal inoculum of *B. cinerea* (Grewal 1982, Laha and Grewal 1983b). Grewal and Laha (1983) also observed that the seed treatment with carbendazim + Thiram®, or vinclozolin, or carbendazim alone at the rate of 0.2% (2g of fungicide per kg of seed) completely eradicated the *B. cinerea* in chickpea seeds. Madhu Meeta et al. (1986a) also studied the efficacy of different fungicides for seed treatment to control BGM and found that Bavistin® (carbendazim) was the best. Singh and Bhan (1986b) reported that 95% of the seedborne inoculum was eradicated by seed treatment with triadimefon at the rate of 0.1%. Singh and Kaur (1990) again confirmed the efficacy of triadimefon at the rate of 0.1% for seed treatment to control BGM. Grewal et al. (1992) observed that soaking of infected seed for three hours in a 0.1% suspension of a mixture of 25% carbendazim and 50% Thiram® can reduce seedborne infection. These workers also observed that this fungicide soaking treatment protected against aerial infection of BGM for about 8 weeks after emergence. Bakr et al. (1993) reported that seed treatment alone was ineffective in controlling BGM. Singh et al. (1997) reported that seed treatment with Bavistin® + Thiram® (1:1) or Indofil M-45®, or thiabendazole, or Ronilan®, or Rovral®, or Bavistin® at the rate of 0.3% controls seedborne *B. cinerea.* Burgess et al. (1997) reported that heat treatment of freshly harvested seed at 50°C for five minutes, or storage of the seed at 20°C for 12 months reduced the frequency of occurrence of *B. cinerea.*

Foliar spray. *Botrytis cinerea* attacks all aerial parts of chickpea. Flowers and young fruits are most susceptible to this disease. Fungicides applied at regular intervals from the appearance of the first symptom of the disease can give considerable control. When conditions are favorable for BGM disease development, along with seed treatment, foliar spray with vinclozolin (0.1%) or carbendazim + Thiram® (1:1, 0.1%), or carbendazim alone (0.2%) at the appearance of first symptoms controlled the disease (Grewal and Laha 1983). Madhu Meeta et al. (1986a) observed that four fungicidal sprays with Bavistin® along with seed treatment with the same chemical reduced BGM incidence and resulted in higher yields. Rewal (1987) reported that Bavistin® 50 WP or Bavistin® + Thiram® gave very good protection from aerial infection even spraying at 14-day intervals.

Pandey (1988) observed that seed treatment with Bavistin® + Thiram® (1:4) followed by three sprays of Bavistin® at 10-day intervals gave excellent control and higher grain yields. Singh and Kaur (1990) reported that seed treatment with triadimefon (0.1%), or carbendazim + Thiram® (0.3%), or Dithane M-45® (0.3%) or Bayton® (0.1%), together with one foliar spray with Dithane M-45®, or Hexacap®, or Thiram®, or thiabendazole, or Bayton®, or triadimefon at 50 days after sowing or at the appearance of symptoms gave complete control of both primary and secondary infection of BGM. Reddy et al. (1990) observed that two foliar sprays of vinclozolin (0.2%) at flowering and podding stages along with other agronomical and cultural management practices discussed above, reduced BGM incidence and increased grain yields at Pantnagar, India. Haware and

McDonald (1992) also confirmed the results reported by Reddy et al. (1990).

Bakr et al. (1993) observed that seed treatment (carbendazim 25% and Thiram® 50%, 1:1) together with two foliar sprays with carbendazim at 14-day intervals gave good protection against BGM disease in Bangladesh. Haware and McDonald (1993) suggested the judicious use of vinclozolin (0.2%) in the integrated disease management of BGM. Singh et al. (1997) reported that foliar spray with Indofil M-45®, or thiabendazole, or Bayton®, or Bayleton®, or Thiram® during the crop growth in Feb-Mar controlled foliar infection. Haware et al. (1997), and Shrestha et al. (1997) reported that one spray with vinclozolin (0.2%) at the time of flowering in the integrated management system controlled BGM incidence. However, Bakr et al. (1997) observed that two foliar sprays with vinclozolin (0.2%) was required to control BGM in Bangladesh. Generally, one spray at flowering followed by another spray after 10 days on a moderately resistant chickpea cultivar provided the best results in terms of disease management and higher grain yield.

Management using biological agents. Although repeated fungicide application can alone achieve the effective management of BGM in chickpea, if the conditions are not favorable for disease development, biological control of B. *cinerea* using species of *Trichoderma* has been reported in some fruit and vegetable crops (Tronsmo 1986, Nelson and Powelson 1988, Elad 1994). D'Ercole et al. (1988) observed satisfactory results in controlling *B. cinerea* of strawberry with *Trichoderma* species. Very limited work has been done on biological control of B. *cinerea* using species of *Trichoderma* in chickpea. Integrating a biocontrol agent with sublethal doses of fungicide seems to be very promising in controlling pathogens without much disturbance of the biological equilibrium.

Mukherjee and Haware (1993) isolated species of *Trichoderma* from the rhizosphere of chickpea, tested them against *B. cinerea* in the laboratory, and identified the most effective isolate of *Trichoderma viride* in controlling BGM of chickpea. Mukherjee et al. (1995) in their further tests, isolated fungicide (vinclozolin) tolerant isolates to be used along with vinclozolin in the integrated BGM disease management system. Haware et al. (1997) reported that there were no differences in BGM incidence and grain yield of chickpea between three sprays of *Trichoderma viride* (10^7-10^8 spores mL^{-1}) and three sprays of vinclozolin (0.2%). These results are presented in Table 2. Burgess et al. (1997b) reported that seed treatment with *Gleocladium roseum* suppressed the sporulation of *B. cinerea* on chickpea seed. In the third working group meeting to discuss collaborative research on botrytis gray mold of chickpea held 15-17 April 1996, at Pantnagar, Uttar Pradesh, India, it was unanimously agreed to use the biological control agent, *Trichoderma viride,* in the integrated disease management of BGM of chickpea.

Table 2. Effect of *Trichoderma viride* on severity of botrytis gray mold (BGM), and yield in BGM nursery, G B Pant University of Agriculture and Technology, Pantnagar, India, 1994/95.

Treatment	Disease rating (1-9 scale)	Yield (t ha^{-1})
Control (no spray)	5.8	1.2
Three sprays of *Trichoderma* (10^7-10^8 spores mL^{-1}) at 20-d intervals	4.0	1.7
Three sprays of Ronilan® (0.2%) at 20-d intervals	4.0	1.8
First spray with *Trichoderma* (10^7-10^8 spore mL^{-1}) + Ronilan® 0.1%; second spray with *Trichoderma* (10^7-10^8 spore mL^{-1}); third spray with *Trichoderma* (10^7-10^8 spore mL^{-1}) + Ronilan® 0.1%	4.6	1.6
SE	±0.204	±0.079
CV (%)	9.1	10.1

Source: Haware et al. 1997.

Conclusion

Although BGM of chickpea has been studied worldwide for several decades, efficient and complete control measures are not yet available to be used by resource-poor farmers in South Asia and elsewhere. Substantial progress has been made in the development of screening techniques to identify resistant sources, but there has been little success especially in identifying higher levels of resistance in cultivated *Cicer* species. However, high and stable levels of resistance have been identified in the wild species. It is expected that highly resistant and high-yielding cultivars endowed with other desirable characteristics will be made available to farmers in the near future. Meanwhile, high priority should be given to participatory on-farm validation of the available components (including moderate levels of host-plant resistance with high yield) of disease management and their integration. Extension, and supplying the seed of available resistant cultivars to farmers should be mandatory for any research and development program. It is expected that collaboration in research on BGM of chickpea through the Botrytis Gray Mold Working Group will increase among the member countries and that this collaboration will provide solutions to location/region specific problems and continue to improve BGM control.

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Salient Points of Deliberation and Recommendations

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The Fourth Meeting of the Botrytis Gray Mold (BGM) of Chickpea Working Group for Asia was held at the headquarters of the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, on 23 Feb 1998. The meeting was hosted jointly by BARI and ICRISAT and attended by scientists from Bangladesh (7), Nepal (1), India (1), ICRISAT (3), FAO (1), and representatives of NGO groups (3) (see participants list). Dr M A Malik, CLAN Country Coordinator and Director (Training and Communication), BARI, welcomed the participants and chaired the meeting. Dr M A Bakr, Coordinator, BGM Working Group, BARI, co-chaired the meeting. The deliberations included presentation of research work done on BGM in Bangladesh, Nepal, and Ludhiana (India) over the previous two seasons, since the third BGM Working Group Meeting in Pantnagar, India, in April 1996. A representative from Pantnagar could not attend the meeting, therefore, BGM work done at Pantnagar was not presented. The salient features of the presentations and items considered for further work are:

- Priorities and a plan of action for the BGM working group were discussed and redefined with main thrusts to be on renewed efforts to enhance host-plant resistance (HPR) and on-farm evaluation and validation of integrated BGM management options in Bangladesh, Nepal, and India.
- Concerted efforts are needed to accelerate research on the incorporation of resistance to BGM following intraspecific hybridization. Scientists of Punjab Agricultural University (PAU), Ludhiana, have identified wild *Cicer* species (*C. judaicum* 182 and *C. pinnatifidum* 188) having higher levels of resistance to BGM than found in cultivated chickpea. Segregating material involving 16 BGM-resistant (tested in green house/lab conditions) accessions derived from eight wild *Cicer* species is available at PAU for further evaluation. Fortunately, these lines have also been found to be highly resistant to ascochyta blight (AB) at PAU.
- The importance of agronomic factors (e.g., sowing date, row spacing, and plant density) and plant characters (e.g., growth habit and open canopy structure) and the basis of these in ameliorating BGM incidence and spread was discussed in detail. Results were presented of the research conducted on these factors in Bangladesh.

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- BGM research in Nepal was discussed. The Nepal Agricultural Research Council (NARC) has shifted the center of BGM research from Rampur in central-western Nepal to Tarahara in the eastern Tarai region. Eastern Nepal appears to be a hot-spot location for BGM screening, but little chickpea is grown by farmers in this region because of this very problem.

Recommendations

The group reviewed the recommendations made by the Third Working Group Meeting (15-17 Apr 1996, Pantnagar, India) and the progress made since then. The following recommendations for the BGM of Chickpea WG were developed during the Fourth Working Group Meeting for follow-up action and appropriate research centers/scientists were identified for each area of research.

- **Survey.** A systematic, regular, and targeted survey of BGM incidence is needed. Geographic Information System (GIS) and Global Positioning System (GPS) technology should be employed to map the incidence, spread, and severity of BGM in Nepal, Bangladesh, and India (Action: Dr M A Bakr for Bangladesh, Dr Gurdip Singh for India, and Mr. P C P Chaurasia for Nepal, with support from ICRISAT).
- **Screening techniques.** There is a need to correlate field, greenhouse, growth room, and laboratory screening techniques for BGM resistance. In particular, the growth room screening procedure at ICRISAT needs to be revisited and the cut-twig technique developed at PAU needs to be evaluated at other laboratories and against other screening methods. The mist spray system at Ishurdi currently offers the best scope for screening "field resistance" to BGM (for example, it can account for canopy characteristics, which cannot be adequately accounted for in growth rooms). This system should be used primarily for screening for host-plant resistance and should receive the necessary support to remain fully operational (Action: ICRISAT and NARS).
- **Sources of resistance.** A systematic approach is needed to assemble all known sources of resistance in a BGM nursery and test this nursery at several locations and with different screening techniques (Action: ICRISAT to coordinate). Screening of as much new germplasm material as possible, including wild types and related species, should be done under the mist system at Ishurdi (Action: Dr M A Bakr and ICRISAT).
- **Incorporation of resistance.** Greater emphasis should be given to incorporating BGM resistance derived from related wild species. A gene pyramiding approach to build moderate levels of resistance is needed (Action: NARS and ICRISAT).
- **Seedborne infection and disease epidemiology.** There is a need to quantify the role of seedborne infection in disease development and to understand and

quantify the role of microclimate. Studies are required to develop disease prediction models. Investigation of pathogenic variability was considered less important as multilocation tests account for race differences. (Perhaps this could be a student thesis study.) (Action: PAU and ICRISAT).

- **Novel approaches to resistance.** Advanced research institutes should examine the basis of resistance to BGM, in the hope of streamlining screening techniques and identifying appropriate resistant genes for transfer (Action: ICRISAT).
- **Rating scale.** The visual rating scale for BGM severity needs to be revised, and standardized and publicized among BGM researchers (Action: ICRISAT and NARS).
- **Integrated disease management.** The Group unanimously agreed to assemble and review options for integrated BGM management. It was decided to have short-term and long-term strategies for location-specific BGM management. On-station research should continue to develop IDM strategies for alleviation of BGM at Ishurdi (Bangladesh), Pantnagar (India), and Tarahara (Nepal), as a long-term strategy. However, research components need to be assembled and validated in on-farm farmers' participatory research in these three countries. ICRISAT will coordinate these activities in collaboration with NARS and NGOs (Action: ICRISAT, NARS, and NGOs).
- **BGM Newsletter.** The Group also felt the need to launch a periodic "BGM Newsletter" to exchange information and facilitate networking on BGM-related research and extension. Dr M A Bakr would be the chief editor and ICRISAT would assist in publication and distribution (Action: Dr M A Bakr, ICRISAT and NARS scientists to contribute articles).

Field Trip Experience of the Group Members

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The group members of the fourth working group meeting participated in a monitoring tour of postrainy season pulses (chickpea, lentil, and lathyrus) in farmers' fields in western parts of Bangladesh, in the greater districts of Faridpur, Jessore, and Ishurdi. The participants on the trip included ICRISAT and FAO participants, and scientists and staff of BARI, including those associated with the Lentil, Blackgram, and Mungbean Development Pilot Project (LBMDPP) of Bangladesh. The major objective was to assess incidence and effects of BGM and other major biotic constraints in farmers' fields and research station trials through observation by subject matter specialists and by interviewing the farmers for their perceptions.

Area Covered and Methodology

The route followed includes the main winter season pulse growing area in Bangladesh. The team had no prefixed criteria for choosing to stop at particular roadside plots. However, stops were selected 20-25 km apart when a substantial area of chickpea cultivation was seen. Along with chickpea, other pulses such as lentil, lathyrus, field pea, faba bean, and long-duration pigeonpea were also observed. At each site participants recorded the incidence of BGM and other diseases on chickpea and lentil. The cropping systems and general agronomic practices followed by the farmers were also noted. The participants could also obtain the views of several farmers on a wide range of topics in a relatively short period. Farmers reiterated that pulses are most important for them and that they need more assistance in appropriate methodology for providing plant protection.

Weather and Disease

Intermittent rains, foggy days with relative humidity ((85%), and cool to moderate temperatures (4°-25°C) throughout the crop season (Nov-Feb) had caused widespread foliar disease problems in chickpea and lentil. Botrytis gray mold was the predominant foliar disease of chickpea throughout. Stemphylium bight was widespread in lentil, along with BGM.

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Summary of Observations Made in Farmers' Fields

- Sole crop and intercrop chickpea stands with varying degrees of BGM infection were seen. Chickpea was in the flowering to mid-pod fill stage and pod filling was generally good once pods had formed.
- Clear-cut differences in degree of severity of BGM with respect to time of sowing of chickpea were observed in Mazlishpur village. Early-sown crops had more severe BGM than late-sown crops. However, at a more "humid" location all plants were severely infected with BGM even though late sown and small in size.
- In several cases, substantial differences in the severity of BGM were not seen between sole crops of chickpea and chickpea intercropped with linseed, wheat, or barley.
- Fusarium wilt was significantly reducing the plant stand at some locations. This was also confirmed as a problem by farmers.
- In general, BGM was less in the late-sown crops. However, initial symptoms of BGM were noticed, and it was anticipated that with an increase in temperature development of BGM disease would also progress.
- The severity of BGM varied from location to location. In general it was between 4-8 on a 1-9 rating scale (9 = most severe damage; 1 = no damage), with no clear date of sowing or cultivar effects consistent across locations.
- Lentil growth was moderate to excellent with poor to fair podding. Inadequate podding was attributed to fungal foliar disease which increased in severity with soil moisture and density of the sole-cropped stand. Lentil was primarily suffering from stemphylium blight and BGM infection although rust and wilts were also seen.
- Poor to fair nodulation in both chickpea and lentil was observed throughout. In general, nodulation was poor in the fields where pulses were sown only occasionally or after two or three crops of rice.

BARI Demonstrations

The BARI LBMDPP staff had sown about 6 ha of lentil demonstration plots near Kaliganj. Additional areas had been planted by farmers. These demonstrations consisted of BARI Masoor 1, 2, 3, and 4 varieties of lentil. Among the four varieties BARI Massor 4 is preferred by most of the farmers because of its bold seed size and high and consistent yields. All four varieties had moderate levels of BGM, stemphylium blight, and stem rot.

Research Stations

Jessore (25 Feb 1998). Most chickpea trials had vigorous vegetative growth (~60 cm plant height) with dense, closed canopies. This location receives more winter rainfall and remains more humid in winter and spring than Ishurdi. It thus provides favorable weather conditions for foliar diseases of pulses.

Mrs F Khatoon, Plant Pathologist, showed the group a number of trials. The BGM observation nurseries, where H 208 was planted both as a spreader and indicator row after every five test entries, were scored by group members. Disease establishment was satisfactory and it was increasing. Of 25 entries, entry numbers 3, 14, and 21 were consistently resistant across three replications (3-4 on 1-9 rating scale). In an agronomic trial ICCL 87322 appeared most promising, perhaps because of its upright, erect canopy, in comparison to H 208 which was almost killed. At this location several test entries had severe BGM infection and would be unlikely to produce any pods.

Ishurdi (25 Feb 1998). Most chickpea trials at the Pulses Research Center, Ishurdi, were sown late. Chickpea vegetative growth was vigorous with dense, closed canopies formed. BGM infection was at its earlier stages and restricted to the lower canopy. Podding was fair to good. In one trial, wilt-susceptible lines had died at an early growth stage leaving a few bare patches.

Experiments on the management of BGM were impressively conducted by Mr A U Ahmed. Treatments comprised Bavistin® spray, late and normal sowing, nipping of young shoots, sole vs intercropping with linseed, wide and normal spacing, and genotypes (Nabin and ICCL 87322). The trial was conducted under the mist spray system, which appeared to be working effectively. BGM was in its initial stages of infection and spread. It was hoped to get convincing evidence from these experiments on the integration of different components of BGM management. However, it was suggested that the mist spray area could in future be best employed for mass screening of germplasm and breeding progenies for BGM resistance.

Also, an experiment on the influence of chickpea cropping systems on *Helicoverpa* management was impressive, but its success will depend on later incidence of pod borer.

In general BGM had just appeared in most of the trials and according to local scientists there was every likelihood of its increasing intensity with a steady rise in temperatures. Susceptible control, H 208, was already showing a 6-7 disease rating. ICCL 87322, a tall, erect, BGM-tolerant line developed at ICRISAT appeared to be the most promising cultivar for use in integrated BGM management.

Among the breeding materials it was interesting to note that a deep-rooted chickpea line, ICCL 85111, was being extensively used as a parent in breeding programs for the Barind, where access to water below the hard plow pan is a key to success of chickpea in this region.

Final Discussion

In the evening of 25 Feb 1998, the BGM WG members met for discussions on their tour observations and to refine action plans further. The practicability of using a fungicide against BGM was discussed in detail, with respect to eventual adoption of this technology by farmers. It was finally decided that it would be worth including as a treatment in on-farm evaluation as adoption of "spray technology" is occurring in the target areas (especially for vegetables). As incidence of BGM is very much affected by macro- and microclimate conditions, a probability analysis is required for target regions, to be able to predict frequency of BGM-conducive conditions. This is a prerequisite to developing effective BGM alleviation strategies. It was decided that Dr M A Bakr would coordinate refined workplans of joint studies, with assistance from ICRISAT (Dr S D Singh for genetic improvement aspects and Dr S Pande for IDM aspects). These plans need to be ready for presentation at upcoming CLAN Review and Planning Meetings and for implementation in the 1998/99 chickpea growing season.

Barind (26 Feb 1998)

Several Group members made a brief trip through the dissected (or high) Barind, which covers about 82 000 ha north of Rajshahi town. Prior to the 1990s, the area was largely left fallow after harvest of transplanted Aman rice. With development and adoption of postrainy season cropping technologies for the region, the area of chickpea and other postrice crops has markedly expanded since 1990 (e.g., chickpea from about 200 ha then to near 10 000 ha currently). Perhaps because of the slight elevation of the region, with less rainfall and lower humidity at ground level, BGM develops to a much smaller extent here than in the alluvial soils of traditional chickpea-growing areas of the country. Micrometeorological measurements are needed to confirm this hypothesis. Chickpea fields examined on this trip showed little sign of BGM infection, although many crops were sown late (in December, after rainfall). Thus, the Barind presents one option for alleviating the BGM constraint in Bangladesh by shifting chickpea production to an agroecological zone less conducive to disease development.

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About ICRISAT

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

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

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

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