Botrytis Gray Mold of Chickpea

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

4-8 March 1991
Joydebpur, Bangladesh

Edited by

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ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1992

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Objectives of the Meeting

D.G. Faris

Legumes Program, ICRISAT

On behalf of the Bangladesh Agricultural Research Institute (BARI) and the Asian Grain Legumes Network (AGLN) I wish to thank you all for coming here today.

The Asian Grain Legumes Network consists of scientists, administrators, and institutions linked together because of their willingness to collaborate on research on chickpea, pigeonpea, and groundnut in Asia. The Coordination Unit (CU) for the network and the research backup is provided by ICRISAT.

To provide answers to specific regional problems, the AGLN has constituted a series of working groups (WG) which bring together experts who pool their knowledge and resources to collaborate in providing answers to the group's mandated problem as quickly as possible. The objectives of the Botrytis Gray Mold (BGM) of Chickpea Working Group Meeting are:

- bringing together researchers from the national programs involved in BGM, to review their research findings and to coordinate future research;
- determining the seriousness and extent of BGM incidence on chickpea in Asia;
- compiling the existing information on BGM of chickpea;
- identifying gaps in our knowledge on BGM of chickpea;
- proposing priorities for the various modules of this research;
- identifying resources and expertise available within and outside this group for conducting priority research;
- assigning research modules to individuals or groups; and
- determining the resources needed, and if necessary, preparing a research proposal for additional funding.

During our field tour of western Bangladesh we will be directly exposed to the problem and will be able to learn from the farmers their perception of the seriousness of the problem. We will also be able to see for ourselves the research being done in Bangladesh on BGM of chickpea.

I wish to thank the Asian Development Bank (ADB) for providing support for this meeting through their grant to the AGLN, and BARI and the Crop Diversification Programme for helping organize this meeting.

Summaries

Integrated Management of Botrytis Gray Mold of Chickpea

M.P. Haware and D. McDonald

Legumes Program, ICRISAT

Chickpea (*Cicer arietinum* L.) is an important grain legume in Asia, Africa, and the Americas. It is particularly important as a source of dietary protein to the largely vegetarian population of the South Asian countries. According to the FAO Production Year Book (1988), chickpea was cultivated on 10 m ha and its production was nearly 7 m t. Though the yield potential of present-day chickpea cultivars exceeds 5 t ha^{-1}, their actual yield is only 0.7 t ha^{-1}. The gap between the actual and potential yields is mostly due to the diseases and pests that affect the crop. In this paper we shall focus on one disease of chickpea—botrytis gray mold—which is of considerable importance in South Asia.

Importance and Distribution

Botrytis gray mold is an important disease of chickpea in northern India, Nepal, Bangladesh, and Pakistan. It was first reported in India in 1915 (Shaw and Ajrekar 1915). Outside the Indian subcontinent the disease has been reported from Argentina (Carranza 1965), Australia (Nene et al. 1989), Canada (Kharbanda and Bernier 1979), and Chile (Sepulveda and Alvarez 1984).

During the 1978/79 crop season, BGM completely destroyed about 20,000 ha of chickpea in the *Tal* area of Bihar state of India. During 1980/81, the disease appeared in epiphytotic form in several parts of Punjab, Himachal Pradesh, Haryana, Uttar Pradesh, Rajasthan, West Bengal, and Bihar states of India causing serious losses (Grewal and Laha 1983). Carranza (1965) reported a 95% crop loss in Jujuy Province of Argentina.

Symptoms

The symptoms of BGM develop on the stem, flowers, leaves, and pods as gray or dark brown lesions covered with erect hairy sporophores and masses of single-celled hyaline spores. The gray fungal growth is evident on flowers and petioles if observed early in the morning. Drooping of the affected tender terminal branches is a common field symptom. In cloudy weather, flower-drop and rotting of plant parts is conspicuous. All affected foliage is discolored.

In conditions of high humidity and low temperature, discrete brown spots develop on the leaflets, and circular to elongate spots form on the branches. Chlorosis and defoliation occur at higher temperatures. Sometimes, tiny black sclerotial masses appear on the dead tissue. These dark brown sclerotia should not be confused with the larger dark or dark brown sclerotia of *Sclerotinia sclerotiorum* that are embedded in a white mycelial mat (Joshi and Singh 1969).

When BGM affects pods, no seeds or only small, shrivelled seeds are formed. A grayish-white mycelium grows on immature seeds. The pod lesions are watersoaked, irregular in shape, and may have black sclerotial bodies scattered throughout the infected areas.

The Pathogen

Botrytis cinerea Pers. ex Fr. is the causal agent of gray mold in chickpea and is the anamorph of the fungus, the teliomorph being *Sclerotinia* (*Botryotinia*) *fuckeliana* (Groves and Loveland 1953). The teliomorph has not been reported on chickpea. It must be emphasized that *Sclerotinia sclerotiorum*, the causal agent of chickpea stem rot, is not the teliomorph of *B. cinerea*. However, the diseases commonly co-exist in chickpea fields.

B. cinerea infects several plant species including chickpea, grape, strawberry, apple, and lentil. The mycelium of *B. cinerea* is septate, brown, the hyphae being 8-16 μ wide; the young hyphae are thin and hyaline. The conidiophores are light brown, septate, erect, and their tips are slightly enlarged bearing small, pointed sterigmata. The conidia are hyaline, one-celled, oval, and are borne in clusters on short sterigmata. The conidia in mass are ash gray in color and measure 4-20 × 4-16 μ. They germinate easily in water by forming a thin, hyaline germ tube.

Sporodochia are formed on host tissues and in culture. Small, unicellular, round microconidia (4-8 μ) are formed on the sporodochia. These conidia do not germinate. The sporodochia soon become nonsporiferous and develop into a sclerotial mass.

Variability

There have been very few studies on pathogenic variability in *B. cinerea* and there is a need to determine whether its races exist.

Epidemiology

There are many reports of botrytis gray mold epidemics in northern India, indicating that *B. cinerea* is well adapted for survival from season to season in this region. It infects several crop species, thus contributing to its survival and multiplication (Coley-Smith et al. 1980).

The fungus survives in the seed. Pod infection is followed by seed infection. The viability of the fungus on infected seed is influenced by relative humidity (Laha and

Grewal 1983). Seeds from diseased plants are small, shrivelled, and the grayish-white mycelium sometimes covers the seed surface. However, external symptoms may sometimes be absent, and a laboratory seed-testing procedure is then required for the detection of the fungus (Haware et al. 1986).

The fungus infects the aerial parts of the plant and produces spores on the infected tissue. *B. cinerea* also produces sporodochia and sclerotia on infected tissues. Studies at ICRISAT Center have shown that infected chickpea leaves decompose within a few months, whereas the stem takes considerably longer. At ICRISAT Cooperative Research Station, Hisar, the fungus survived in infected tissues from January to August.

B. cinerea conidia require free moisture on the plant surface for infection. Studies done at Hisar and the G.B. Pant University of Agriculture and Technology, Pantnagar, India, during the 1986/87 season indicate that chickpea is infected at a very early stage of its growth. Initial infection seems to occur in the lower part of the plant and subsequently spreads to the upper leaves when environmental conditions favor development (Henrik J. Hansen - personal communication). Moist conditions and moderate temperature favor disease development. The relative epidemiological importance of seedborne inoculum and other inoculum produced by *B. cinerea* has not been fully elucidated for botrytis gray mold of chickpea.

Chemical Control

In blotter tests, seed treatment at 2 g kg^{-1} seed with carbendazim + thiram (Bavistin® 25% + thiram 50%, 1:1), vinclozolin, or carbendazim alone completely eradicated the seedborne inoculum of *B. cinerea* (Grewal and Laha 1983). Recently, in a growing-on test, Singh and Bhan (1986) reported that 95% of the seedborne inoculum was eradicated by seed treatment with triadimefon (1 g kg^{-1} seed) followed by Dithane M-45® (3 g kg^{-1}), or triadimenol (1 g kg^{-1}), or thiabendazole (1 g kg^{-1}), or thiram (3 g kg^{-1}), or carbendazim + thiram (3 g kg^{-1}). When conditions are favorable for infection, foliar sprays with vinclozolin (0.1%), carbendazim + thiram (0.1%, 1:1), or carbendazim alone (0.2%) should be applied at the first appearance of symptoms (Grewal and Laha 1983). However, fungicides alone will not control the disease if climatic conditions favor infection.

Host Resistance

Extensive screening of chickpea germplasm in India and Nepal has failed to identify any genotype with a high level of resistance to BGM. (Haware and Nene 1982; Rathi et al. 1984). Several lines (ICCs 1069, 1913, 3640, 4954, 6299, and 7111) found to have field resistance at Pantnagar were shown to be completely susceptible when grown at Rampur in Nepal. Although some lines are not damaged in the vegetative stage, severe flower infection and lack of pod-set is common.

Disease Management

In areas of severe BGM infection, integrated disease management should be practised. The development of the disease depends on the density of the initial inoculum, the infection rate, the growth stage of the plant, and the crop duration. Results from field experiments at Pantnagar from 1988/89 to 90/91 indicated that the disease incidence was much lower in a tall and compact genotype (ICCL 87322) than in a bushy and spreading genotype (H 208). Two foliar sprays of vinclozolin (0.2%) suppressed the disease in both cultivars and there was a significant increase in grain yield. Sowing the healthy seed of the tall and compact chickpea genotype with wide inter-row spacing, together with limited use of an appropriate fungicidal spray should reduce the severity of the disease. Such a practice should also be effective against Alternaria and Stemphylium blights of chickpea.

Future Research Strategies

More studies on the ecology of *B. cinerea* and the epidemiology of botrytis gray mold are needed in order to develop effective disease management procedures. The role of infected seed and host debris as primary sources of inoculum should be further investigated. Studies on physical and biological factors associated with disease development will contribute to a better understanding of the disease. Information on the chemical control of the disease is available but further experimentation is needed to examine the economics of pesticide application. The extent of pathogenic variability in *B. cinerea* must be determined. Since high-level resistance to botrytis gray mold of chickpea is not available in the current world germplasm collection maintained at ICRISAT, integrated disease management, employing such strategies as the use of tall and compact genotypes, modification of cultural practices, and provision of disease-free seed should be developed.

Germplasm enhancement and utilization of wild *Cicer* species are suggested as promising ways to attain resistance that could be used in the management of this disease.

Botrytis Gray Mold of Chickpea in India

J.S. Grewal, Mahendra Pal, and Neena Rewal

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Botrytis gray mold was observed in several chickpea fields in the *Terai* region of Uttar Pradesh by Joshi and Singh (1969). It appeared in an epiphytotic form and destroyed chickpea crops over 20,000 ha in the Barahiya and Mokamah areas of Bihar in January 1979. The disease caused 70-100% losses in yield in the Central State Farm, Hisar, and in parts of Punjab in 1981 (Grewal and Laha 1983). It also caused heavy losses to the crops in West Bengal, Bihar, Uttar Pradesh, Punjab, and Haryana states (Grewal 1982).

Symptoms

The fungus forms gray or dark brown lesions on leaflets, branches, and pods. The lesions are covered with erect hairy sporophores under high-humidity conditions and temperatures favorable for the growth of the fungus. Growing tips and flowers are particularly susceptible to infection. The infected plants exhibit general yellowing and there is a shedding of the infected flowers (Grewal and Pal 1986).

Joshi and Singh (1969) reported that branches broke off from the point of infection. The fungus forms black sporodochia on the thick stems. Kharbanda and Bernier (1979) reported chlorotic spots on young leaves and twigs which later on turned into dark brown lesions. The twigs bore numerous fungal fruitifications. Finally the plants exhibited yellowing, and were killed.

Strain Variation

The study of strain variation in *Botrytis cinerea* is of vital importance as the strains may show not only differences in their cultural characteristics but also in their nutritional requirements and relative aggressiveness on different varieties of chickpea. Isolates of *B. cinerea* collected from different locations in India exhibited marked cultural variations, and were grouped into conidial, mycelial, and sclerotial strains (Rewal and Grewal 1989). The conidia of the three groups exhibited variations in the temperature, humidity, and light they require for germination.

Physiologic Specialization

The knowledge of the pathogenic variability in a fungus is important in order to develop resistant cultivars. To study the physiologic specialization in *B cinerea*, a number of chickpea lines were tested for disease reaction to six different strains of *B. cinerea* collected from different locations in India. The six strains infecting chickpea could be divided into five distinct pathotypes on the basis of their reaction on a set of five chickpea lines, BG 256, RSG 3, ICC 6250, RSG 2, and BGM 413 (Rewal and Grewal 1989a). Further research is required on the occurrence of physiologic races of *B. cinerea* in order to develop effective disease management procedures.

Perpetuation

Botrytis gray mold of chickpea has been found to be externally as well as internally seedborne. Chickpea seeds collected from the Central State Farm, Hisar, were found to be infected with *B. cinerea* to the extent of 18.5% in cv. H 355 (Grewal and Laha 1983). The infection decreased with an increase in the storage period of the seeds. The fungus remained viable in infected seed and plant tissues at room temperature till the next normal sowing time of chickpea in India. Laha and Grewal (1983) reported that conidia produced on infected plants remained viable in the field for 10 weeks. The fungus was found to be viable in infected seed and plant debris stored at 18°C for five years (Grewal 1988).

Disease Management

Infected seed and plant debris may be primary sources of *B. cinerea* infection in the field. Since the disease is seedborne, treatment of the seed with a mixture of 25% carbendazim and 50% thiram at the rate of 2.5 g kg^{-1} of seed, eliminated the external and internal infection of *B. cinerea* in chickpea seeds (Grewal 1982; Laha and Grewal 1983a). Soaking the infected seeds for three hours in a 0.1% water suspension of these fungicides also controlled the seed infection. This protected chickpea plants against aerial infection up to eight weeks after emergence whereas two foliar sprays with a mixture of 25% carbendazim and 50% thiram at 0.1% or carbendazim 50 WP alone at 0.2% at 14-day intervals provided complete protection against aerial infection by *B. cinerea*.

Cultivation of disease-resistant chickpea varieties is probably the cheapest and the most effective method of control. Chaube et al. (1980) screened hundreds of germplasm lines for resistance to botrytis gray mold and reported lines ICCs 1069, 6250, 7574, and 10302 as being disease-resistant. Singh et al. (1982) reported six lines, GLs 635, 699, 907, 926, 929, and 930, to be resistant to gray mold. Haware and Nene (1982) observed that none of the chickpea lines tested in a plant propagator was resistant to *B. cinerea* in limited screening trials. Rathi et al. (1984) reported lines ICCs 1069, 6250, 7574, and 10302 as being resistant to *B. cinerea*. Singh and Kapoor (1985) recommended chickpea lines ICCs 1069, 4000, 5033, P 1528-1-1, P 2129, CPI 56566, JM 995, and E 100 Y as being resistant to *Ascochyta rabiei* and *B. cinerea* for breeding varieties resistant to blight and gray mold.

Further research is required to understand better the disease scenario as well as to evolve more effective disease management strategies. The techniques for assessment of losses should be standardized; the relationship and interaction between the genes of the host and the pathogen and the inheritance of disease resistance should be studied; disease-free areas should be identified for the production of disease-free seed; and work should centre around evolving durable and multiple-disease-resistant lines.

Epidemiology of Botrytis Gray Mold of Chickpea

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Reports of BGM epidemics in different parts of the world indicate that the pathogen has a definite and efficient mechanism of survival from one season to another. However, detailed information about its survival and its epidemiology, is scarce.

Survival of the Pathogen

The survival of *B. cinerea* in nature from one season to the next may be through continued activity and growth, either parasitically or saprophytically, or as a dormant structure.

Crop debris. *B. cinerea* survives saprophytically in the soil on infected crop debris. Studies at Pantnagar indicated that the fungus survived mainly on plant debris stored in a laboratory and/or in debris on the soil surface but did not survive in the soil at a depth of 15 cm. There is a need to identify the soil conditions under which the pathogen survives and the duration of its survival.

Seed. The role of seedborne inoculum in the epidemiology of BGM of chickpea has not yet been clearly established. When there is severe infection, pods are also attacked resulting in the formation of small, shrivelled seeds in the infected pods. The survival of *B. cinerea* in/on seeds decreased with an increase in storage time. The fungus could not survive for more than 8 months when the infected seeds were stored at 40°C.

Host range. *B. cinerea* is a facultative parasite and can infect several crop species. In a recent study we observed that *B. cinerea* could infect 21 plant species.

Effect of Environment

Relative humidity (RH) and temperature are the two important factors affecting the infection and development of BGM of chickpea. A relative humidity of 95% or above for a few hours during the day and a dense canopy are most conducive for infection and rapid spread of the disease. Maximum disease severity occurs at 25-30°C temperature and 95-100% RH. During the epidemic years 1980/81 and 1981/82, weather data from Pantnagar suggested that during the crop season (Nov-March), heavy rainfall and more rainy days were recorded which lead to early vegetative growth of the plants which ultimately lead to high disease severity. On the other hand, during moderate disease years (1982/83) fewer rainy days and less rainfall were recorded.

Botrytis Gray Mold Resistance in Chickpea

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Among the pulses, chickpea occupies an important position. More than 90% of the area under chickpea in the world and approximately 90% of its production is in Asia. In India, chickpea yields are very low. In fact, the average chickpea yield of 0.75 t ha^{-1} compares unfavorably with the yields of important cereals. One of the main reasons for the low yield is the losses caused by diseases and pests. Botrytis gray mold of chickpea is a major yield reducer.

Botrytis gray mold can be controlled with the use of resistant cultivars and effective fungicides for seed treatment and foliar application.

Sources of Resistance

Many reports on the identification of resistance to botrytis gray mold have appeared in India. The following resistant lines have been identified at ICRISAT: ICCs 062, 1069, 1903, 4936, 5035, 6250, 7574, 8865, 8928, and 10302.

Recently, some resistant and moderately-resistant genotypes have been developed at the Indian Agricultural Research Institute, New Delhi, India. They are, BGs 276, 298, 299, 303, 309, 327, and 257. Likewise, moderately-resistant genotypes have been reported from Pantnagar, Hisar, Kanpur, and Ludhiana. However, genotypes with high levels of resistance to BGM are not available.

Mode of Inheritance of Botrytis Gray Mold in Chickpea

Very little information is available about the inheritance of resistance to botrytis gray mold in chickpea. Rewal and Grewal (1989b) indicated that it was governed by monogenic dominance in two crosses, and other two crosses showed epistasis interaction. Tewari et al. (1985) and Chaturvedi and Singh (1991) have also reported monogenic dominance of resistance against botrytis gray mold in chickpea. These studies suggest that a major gene is involved in resistance to gray mold in chickpea.

Breeding for Disease Resistance

The development of BGM-resistant chickpea varieties is obviously the only effective way of reducing losses. Lack of information about the source of resistance and its inheritance pattern has hampered the progress of the disease-resistance breeding effort. A comprehensive breeding program has been started at the Indian Agricultural Research Institute, New Delhi. BGM-resistant lines from different centers in India were assembled and were crossed with *desi* and *kabuli* types. Plants of the F_2 generation were grown in natural and artificially inoculated fields. Disease-free plants were selected and the F_3 progenies were raised at Dharwad in Karnataka state, and F_4 progenies at Delhi for field screening. All the promising lines were bulk harvested in the F_5 generation. The pedigree method was employed in developing these lines. A few promising lines are in advanced yield trials.

Botrytis Gray Mold of Chickpea in Bangladesh

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Chickpea is one of the major pulse crops of Bangladesh. It stands third among pulses in area and production. Almost 80% of the area under chickpea is in the districts of Rajshahi, Pabna, Kushtia, Faridpur, and Jessore. The major biotic stress factor in chickpea cultivation is disease, which is responsible for yield reduction.

Occurrence

Botrytis gray mold is one of the major diseases of chickpea in Bangladesh. However, the disease does not occur every year and all over the country. It was documented for the first time in 1981 (RARS 1981). But it is suspected that the disease might have existed in the country for a long time earlier. Since 1981 the disease has been monitored in the farmers' fields. In 1988 it appeared in a devastating form and damaged almost all the chickpea crop in the country. During 1988, rainfall had occurred from mid February to March 10, which might have resulted in luxuriant growth with a dense canopy, favoring the development of botrytis gray mold. The disease occurred again in the following year and damaged the crop throughout Bangladesh.

Extent of Damage

Although no quantitative data on the extent of damage caused in Bangladesh by BGM is available yet, it is evident from observations in the farmers' fields that the disease can cause up to 100% damage. Damage caused by the disease was estimated to be 80-90% in 1988 and 70-80% in 1989.The disease also occurred in 1990, damaging the late-sown crop.

Studies on the Development of the Disease

Studies were undertaken on the development of the disease during the 1988-89 and 1989-90 cropping seasons and were also being pursued during the 1990-91 season. In conditions of high humidity and a dense canopy of the crop, the infection was observed in the first week of February at the Regional Agricultural Research Station (RARS), Ishurdi. Varietal differences exist in the development of symptoms. The temperature and relative humidity (RH) during the onset of the disease recorded at 0700 and at 1300 were 14°C and 89% and 26°C and 77% respectively. Maximum infection was observed from 13-26 February, during which the average temperature ranged from 17 to 28°C and the RH was between 70% and 97%.

Symptoms of the disease were observed on leaflets, flowers, and pods. The fungus forms gray or dark brown lesions on leaflets, branches, and pods. They are covered with erect, hairy sporophores in conditions of high humidity. The flowers and growing tips, particularly those inside the canopy, are the most susceptible to infection. The plants which exhibit general yellowing ultimately turn gray. The leaves outside the canopy, however, remain green. Seeds collected from the infected pods are smaller, shrivelled, and sometimes have mycelial growth on their surface.

Etiology of the Disease

The etiology of BGM has not been studied in Bangladesh. The pathogen has been reported to have a wide host range. The inocula exist in the environment (air). In favorable weather conditions, the pathogen sporulates profusely. It has been found to remain viable on infected plant debris present along with seed, and is externally as well as internally seedborne.

Botrytis Gray Mold of Chickpea in Nepal

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Chickpea is one of the important winter grain legumes of Nepal. In 1989 it ranked third in area (28 800 ha) and production (17 900 t) among the grain legumes, with an average productivity of 0.6 t ha^{-1}. It is grown from the eastern to the western *Terai*, in the inner *Terai*, and in the valleys. Being a drier region, the western *Terai* holds better promise for chickpea production. The yield potential of promising varieties is more than one t ha^{-1} in research farms. Disease is one of the factors causing low chickpea yields and gray mold is one of the major constraints to its production.

In Nepal, BGM epidemics occur almost every year, resulting in an estimated yield loss of 66% on experimental stations. The annual yield loss in farmers' fields is about 15%. The initial symptoms of the disease can be observed during the second or third week of February. The fungus survives as sclerotia or as mycelium in plant debris and seed. Profuse sporulation occurs in wet weather. Conidia are an important source of inoculum in BGM epidemics. The optimum temperature for growth, sporulation, and spore germination is between 15 and 25°C. The incidence of gray mold is the highest in warm and moist conditions, for this allows the production of more inoculum. Relatively long, wet periods are necessary for successful infection. A BGM epidemic is usually characterized by heavy rainfall as well as more rainy days. The fungus has a wide host range which includes fruits, vegetables, and other field crops (Shahu and Sah 1988).

The severity of the disease has been observed to vary significantly in Nepal according to the date of sowing. Delayed sowing, for instance, significantly reduced the disease severity—and also reduced the total biomass significantly.

Disease Resistance

A large number of exotic and indigenous lines are screened at Rampur every year against botrytis gray mold of chickpea. None of the genotypes has yet been reported to be resistant to gray mold. A few lines reported to be tolerant to it (NGLRP 1990) are given in Table 1.

Table 1. Reaction of chickpea genotypes to botrytis gray mold at Rampur, 1988/89 and 1989/90.

Disease Score[1]	Genotypes			
1-3	0			
4-5	ICCL 82108,	ICC 4102-41,	ICCL 86313,	ICC 4102-33
	ICC 4102-21,	ICC 4102-38,	ICC 4102-25,	ICC 4102-42,
	ICC 4102-32,	ICC 4105-13,	ICC 4102-39,	ICC 4105-43
	ICC 4104-13,	Pant G 114,	ICC 4104-2,	Gaurav
	ICCL 86237,		Dhanus	
6-9	159 Genotypes			

1. 1 = No symptom, 9 = Plant killed

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Proposed Work Plan for Botrytis Gray Mold of Chickpea Working Group

The following work plan was developed during a meeting of the Botrytis Gray Mold of Chickpea Working Group on 7 Mar 1991 at BARI, Joydebpur, Bangladesh, by a group of scientists directly associated with research on this disease.

The development of this work plan followed a technical session on 4 Mar 1991 describing the existing knowledge about BGM of chickpea and a two-day visit to Jessore, Ishurdi, and Rajshahi in western Bangladesh to see the problems caused by this disease, to discuss them with the farmers, and see the research being conducted on this disease.

The work plan is intended to outline the research that is required on BGM of chickpea and suggest where this research could be done. It proposes the development of a working group to review the progress of this research and the direction it should take.

This plan splits the research into four major components: surveys, genetic resistance, cultural practices, and epidemiology. It was emphasized that the integration of all these components is essential to provide answers towards the control of BGM of chickpea. It was also emphasized that additional funding would be required to ensure the work plan's effective operation.

Surveys

Presentations at the technical session reported dramatic losses in chickpea yields, with losses over vast areas of Bangladesh reaching 80-90% in successive years. The working group found that farmers in certain areas have accepted the risk of crop failure knowing that in good years chickpea can give high yields. However, during our trip we also observed large areas formerly sown to chickpea now sown to other pulse crops, such as lathyrus, with fewer problems from diseases. Similar yield losses from BGM in chickpea have been reported in some parts of India and Nepal.

These reports indicate that yield losses from BGM in chickpea can be a serious constraint to production, and as such warrants research to find effective methods to control it. However, the meeting recommended that formal surveys should be conducted in Bangladesh, India, Nepal, and Pakistan to assess the actual economic losses, determine where and when the disease is most prevalent, and ascertain the farmers' perception of this problem.

Genetic resistance

Normally the preferred method for controlling a disease is the use of resistant varieties. In the case of BGM of chickpea, high levels of resistance are yet to be verified. Therefore, methods which clearly and consistently identify resistant material by screening appropriate material must be made available. The following series of activities were suggested for the work plan:

Screening. A standard and repeatable screening methodology should be used. This screening contains the following components:

- A standardized inoculation level. Field and greenhouse methods already exist but need to be uniformly applied;
- A standardized disease measurement scale;
- A standardized set of controls with known levels of resistance. This could be integrated with the development of a set of differential varieties; and
- Confirmation that greenhouse and field measurements are interchangeable.

The following locations were identified as being appropriate for BGM screening nurseries for chickpea:

Bangladesh	Regional Agricultural Research Station, Ishurdi (lead) Regional Agricultural Research Station, Jessore (backup)
India	G.B. Pant University, Pantnagar (lead in collaboration with ICRISAT) Pusa (backup) Berhampore (possibly) Ludhiana (possibly) IARI (possibly) ICRISAT Center (greenhouse screening)
Nepal	Rampur (lead) Nepalgunj (backup)

Material for screening.
- Germplasm—ICRISAT is screening the world collection in its greenhouse.
- Improved germplasm and breeding material - Pantnagar in India, Rampur in Nepal, and Ishurdi in Bangladesh are screening breeding lines for resistance. Eight-way crosses have been made at ICRISAT Center and are being screened in order to enhance resistance.
- Wild species accessions are being screened for resistance at ICRISAT Center and sent to Ishurdi. ICRISAT is developing methods including embryo rescue technique to allow crosses between cultivated genotypes and resistant wild species accessions to transfer resistance characteristics from the wild species.
- Mutations - This method is being used by the Bangladesh Institute of Nuclear Agriculture (BINA), the Nuclear Institute for Agriculture and Biology (NIAB) in Faisalabad, Pakistan, and by ICRISAT at Rampur, Nepal. This approach may be expanded—especially if other methods fail.

Coordinate crossing programs. An effort should be made to ensure that a broad spectrum of parents are used while minimizing redundancy, and that appropriate, locally adapted varieties are included, especially when material is exchanged.

Exchange of material. This can include material at different levels:

Parents	– locally adapted material – appropriate plant types (tall) – potentially resistant material
Segregating material	– usually in F_3 and F_4 from crosses made involving BGM-resistant parents.

Exchange of visits among scientists. This can be done so that scientists:

- Agree upon a uniform screening and rating methodology;
- Develop an integrated crossing program across countries; and
- Observe the performance of material across locations in order to identify stable BGM-resistant lines, and use them in breeding programs.

Cultural Control

Observations indicate that the incidence and severity of BGM in chickpea is highly dependent on environmental factors. The working group felt that a better understanding of the various cultural practices and their interaction could help to achieve a greater control of this disease. Cultural control was covered in the work plan as follows:

Seed health. BGM can be carried on the surface of chickpea seeds but is not systemic. Results have shown that badly infected seeds do not germinate, and infected seeds that do germinate do not directly provide inoculum to the crop.

It was agreed that it is important to have BGM-free seeds because of the debilitating nature of this disease on young seedlings when present on the seed.

Research on seedborne BGM and seed health will be carried out at the Bangladesh Agricultural University at Mymensingh, Bangladesh.

Agronomic practices. Several agronomic practices have been identified which minimize yield losses due to BGM mainly by creating a microenvironment less favorable to its development or by moving the susceptible phases to a period when there is a lower probability of conditions conducive to disease development. The following practices have been used but need further refinement:

Time of sowing. Usually sowing time is constrained by the local cropping systems which can limit choice. Early sowing generally results in a heavier canopy which usually encourages the buildup of inoculum within the crop. Late sowing, while usually producing less canopy, can make the reproductive phase coincide with conditions (rainfall) conducive to heavy BGM infestation. Recommendations need to be developed for the time of sowing that minimizes the risk of having weather conditions favorable for BGM when the crop is in its reproductive phase. Documenting and analyzing the existing data could be a useful way to start further investigations. It might also be appropriate to look at the interaction of long- and short-duration chickpea varieties with sowing time.

Spacing. Wide spacing between plants can effectively reduce loss due to BGM but it can result in a lowering of yield if there is no BGM.

Soil texture and moisture. There is a need to explain BGM development and its relationship and interaction with soil texture and moisture.

Soil fertility. The presence or absence of certain soil nutrients and soil pH may have a marked effect on the development of BGM. This relationship is unclear and needs further research.

Chemical control. Chemicals can directly or indirectly control BGM through their effect on plant growth.
Seed treatment. Seed treatment can give plants an excellent start and a certain degree of protection to the seedling for up to 35 days. It may be worth examining the developing crop to see if this protection slows the development of the BGM inoculum.
Phytocides. It is well documented that spraying vinclozolin or thiram + carbendazim (1:1) gives good control of BGM of chickpea. It is important to examine the economics of sprays and develop a formula for forecasting when spraying should be done.
Growth regulators. It may be possible to reduce BGM by reducing the vegetative growth using growth regulators like Pix (mepiquat chloride). This and other growth regulators can be tested to see if they have the desired effect on BGM development.

Epidemiology

This component mainly deals with the basic research associated with BGM of chickpea. It was felt that these studies are most ideally done at universities, in laboratories in developed countries, and at ICRISAT. These studies are essential to the understanding of disease development to support the more applied research discussed so far, and to help in adjusting existing research projects or starting new applied research.

Mode of action. Such research would help in understanding the saprophytic and parasitic phases of BGM, help identify the predisposing factors in the plants, the environment that causes the pathogen to move from one phase to the other, and quantify the buildup of inoculum in the crop.

Microclimatic studies. This research needs appropriate equipment to measure the microclimate in and immediately above the crop and its influence on disease development and severity. Work on this aspect is being conducted at Pantnagar, India. If the equipment is provided, such studies could also be conducted at stations where sufficient disease is consistently present and where there are plant pathologists to monitor the disease's progress. These could include, besides Pantnagar, Ishurdi in Bangladesh, Rampur in Nepal, IARI in Delhi, and NIAB in Faisalabad, Pakistan.

Pathogenic variability. Breeders must know what races/pathotypes of *B. cinerea* are present so that they can provide suitably resistant material. Work on identifying a set of host differentials must continue to be able to identify the races/pathotypes.

Controlled-environment studies. The studies at ICRISAT should be continued and similar studies conducted in laboratories in developed countries. These studies can form the base for strain-difference studies in a third country where BGM is not a problem.

Growth model. The epidemiology and climatic factors identified through the research outlined above can be used in refining the growth model being developed for chickpea. This can be used to predict the development of BGM in chickpea under a variety of conditions.

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Integrated disease control. The most effective control of BGM in chickpea will come from finding the most appropriate options among those considered above and bringing them together to provide an integrated control package. The factors to consider could include resistance, plant type, sowing time, spacing, soil moisture, fertilizers, intercropping, and chemicals. Such a package can only be developed through the activities of interdisciplinary teams. Also, great progress should be possible through the sharing of information.

Working Group. The group considered that the best way of developing interdisciplinary teams for collaborative research on BGM of chickpea, and for sharing information would be to constitute a Working Group on BGM of Chickpea. Ideally such a group should have a pathologist, an agronomist, and a breeder from each of the four countries (Bangladesh, India, Nepal, and Pakistan) and from ICRISAT, and scientists from laboratories in developed countries involved in botrytis gray mold research.

It was agreed that an effort will be made to conduct research in these countries based on the generalized work plan given above. If funding can be found, it was suggested that the scientists most directly involved with the components above (essentially breeders for genetic resistance, agronomists for cultural control, and pathologists for screening and epidemiology) can plan collaborative research. It might be necessary to do this planning only through correspondence or during visits of staff from country to country.

Next meeting. It was further agreed that there should be a follow-up review and planning meeting of the whole working group in about two years (1993) possibly in Nepal. The coordination of this working group at least until the 1993 meeting can be provided by the AGLN Coordination Unit at ICRISAT in collaboration with the ICRISAT chickpea pathologists, breeders, and agronomists.

Outreach. The information generated by this working group will only be useful if it is tested on-farm and, if appropriate, made available to farmers. Consideration therefore needs to be given to starting on-farm research and testing of the technology developed and extending it to the farmers.

Funding. Efforts will be made by the AGLN Coordination Unit to identify funding within countries and on a regional basis to support the activities of the BGM of Chickpea Working Group.

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