



Wheat Special Report No. 15

**Research on Barley Yellow Dwarf:
State of the Art of the CIMMYT
Program and Its Future Research Focus**

Lukas Bertschinger

December 1994

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Note on the Timing of this Wheat Special Report

This Special Report was actually prepared in July 1993, However, for various reasons, it was not published until December 1994. With the departure of Lukas Bertschinger from CIMMYT in October 1994, the plan outlined loses some of its immediate relevance. Even so, this document includes a review of BYD research at CIMMYT and an assessment of the global importance of BYD. This report will help BYD workers to understand past research efforts of this institution in the area of BYD and to shape any future ones. For convenience, an appendix has been added that summarizes the research achievements of the BYD Section since July 1992 in the research areas outlined, and a corresponding publication record.

Note on Citing this Wheat Special Report

By sharing research information in this Wheat Special Report on CIMMYT's work with barley yellow dwarf luteoviruses, we hope to contribute to the advancement of research on this disease and to the importance of shared knowledge. However, the information in this report is shared with the understanding that it is not published in the sense of a refereed journal. Therefore, this report should not be cited in other publications without the specific consent of the CIMMYT Wheat Program.

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Preface

This Wheat Special Report is motivated by changes in leadership and funding of CIMMYT's research on barley yellow dwarf viruses (BYD viruses). In 1991, P.A. Burnett, who headed the section in the 1980s, left CIMMYT. R. Ranieri then provided leadership before his transfer to Purdue University for Graduate studies. Between June 1992 and October 1994, the BYD Section was headed by L. Bertschinger. This document outlines:

- The most important points and essential findings from CIMMYT's research on BYD viruses and from projects of other institutions over the past few years.
- The future research on BYD viruses and guidelines for CIMMYT's work.

A draft version of this Special Report was sent to program directors, subprogram leaders, section heads and international staff members of the Crop Protection (CP) Subprogram of CIMMYT's Wheat Program. It was discussed and modified. Conclusions were derived from several meetings at CIMMYT in 1992 (CP staff meeting, October 28; Wheat Program prebreeding priorities, December 4; Genetic improvement-CP interactions, December 7). The report has been approved by the Wheat Program's directing staff and the Subprogram leader to be the document for guiding CIMMYT's BYD Section in the coming years, or until such time that a further plan is elaborated. It is not the purpose of this Special Report to present a complete and detailed review of CIMMYT's BYD Section and the published achievements in BYD research worldwide. Only principal avenues for CIMMYT's future BYD research are described. Selected references are given which are considered essential. The operational details of the section's program (projects, budgeting, networking, etc.) will be documented as it develops.

CIMMYT is, primarily, a germplasm institute. This Special Report, therefore, focuses on germplasm issues. Most of the research and activities related to viruses in CIMMYT's Wheat Program have emphasized BYD viruses and will do so in the future. However, other viral pathogens of small grain crops may require attention in the future. Although, this report focuses on BYD viruses, the general research strategy may be applied to other cereal viruses.

E.E. Saari

Former Leader, Crop Protection Subprogram

Barley Yellow Dwarf: The Disease

The pathosystem

Barley yellow dwarf (BYD) is the most economically important and widespread virus disease of small grain crops in the world. The disease is caused by a group of related viruses, which are aphid-transmitted and belong to the luteovirus group, members of which cause the yellows diseases. The BYD luteoviruses (BYDVs) are presently subdivided in two major subgroups based on serological relationships (Rochow 1970a, Rochow and Duffus 1981), cytopathological ultrastructure of infected cells (Gill and Chong 1979), and dsRNA profiles obtained from infected tissue (Gildow et al. 1983). Subgroup 1 includes the isolates (strains) PAV, MAV, and SGV, while subgroup 2 includes the isolates RPV and RMV. The acronyms were originally chosen according to their typifying aphid vector species (e.g., RPV for *Rhopalosiphum padi* virus; Rochow 1959, 1967, 1971). These names have been guiding BYD nomenclature since the 1970s, but with the characterization of "new" types (e.g., GPV in China) and new diagnostic techniques, they are presently questioned, and therefore, BYDVs might be renamed in the near future. These viruses are persistently transmitted, meaning that once an aphid acquires the virus, it will transmit it for life. The virus is not known to multiply in the insect. Newborn nymphs (young aphids) are virus-free and acquire BYDVs by feeding on infected plants.

BYDVs can infect more than 100 Gramineae species and more than 20 aphid species have been reported to be vectors of a BYD virus. The virus partially plugs the phloem, interfering with translocation, and infection can cause severe stunting of plants, inhibit root formation, delay heading, and consequently reduce yield. Disease symptoms vary depending on the crop species or cultivar affected, including yellow or red leaf discoloration, which begins at the leaf tip and margins and moves rapidly down the whole leaf, stunting, reduced tillering and stiffening. Often, the symptoms of BYD in bread wheat, durum wheat, and especially in triticale are not particularly apparent. Furthermore, the symptoms can be confused with nutrient deficiencies or toxicities, or by the presence of other diseases such as rusts and foliar blights.

The pathosystem of BYDVs is extremely complex. **Figure 1** may be one way of conceptualizing this complexity arising from the interaction between virus, host plant, and virus vector with the environment and time.

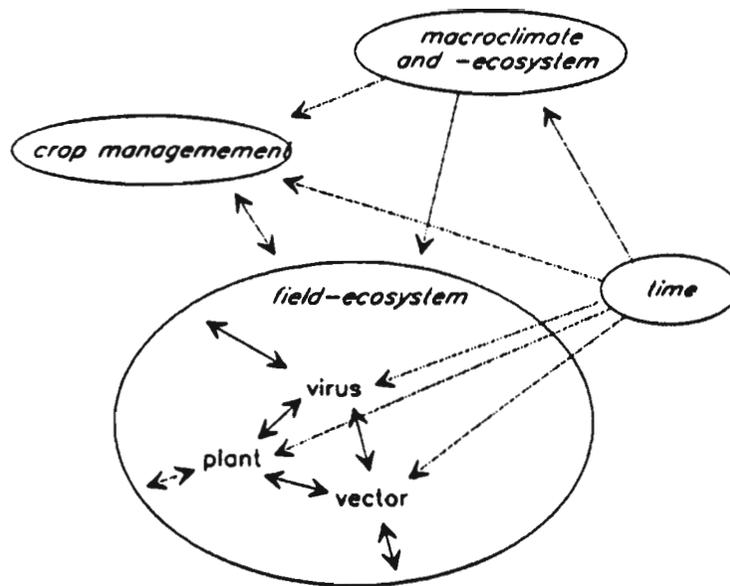


Figure 1: Conceptualization of a pathosystem of a vector-transmitted plant virus.

World wide distribution

BYDVs are ubiquitous across the globe where Gramineae (wild or cultivated) are grown. They are the most common and widely distributed cereal viruses in the world. Incidence studies, particularly in the developing world, have been conducted only in some countries (**Figure 2**). Significant differences in strain prevalence and incidence between different zones in Latin America and Africa have been determined (**Figure 3**). In bread wheats, yield losses after artificial introduction of viruliferous aphids into field plots ranged, on average, from 14 to 50%, depending on the growth stage infected (81% highest), in barleys from 19 to 55 (93% highest), and in oats from 22 to 75 (88% highest) (compiled by Pike 1990). BYD viruses are a serious problem for crop productivity especially, as considered until now, in high-rainfall areas. Only in a few developing countries has average yield loss been estimated or have yield loss studies been conducted (**Figure 4**).

Research on BYDs: Current Trends and Achievements

The world

Diagnostic tools--Since BYDVs can not be clearly identified by symptoms (symptomless plants, similar symptoms caused by other agents/environmental conditions, nonstrain-specific symptoms, etc.), other tools are needed for unequivocal identification of BYDVs. The presence of plant viruses has also been detected in plant tissues by other diagnostic

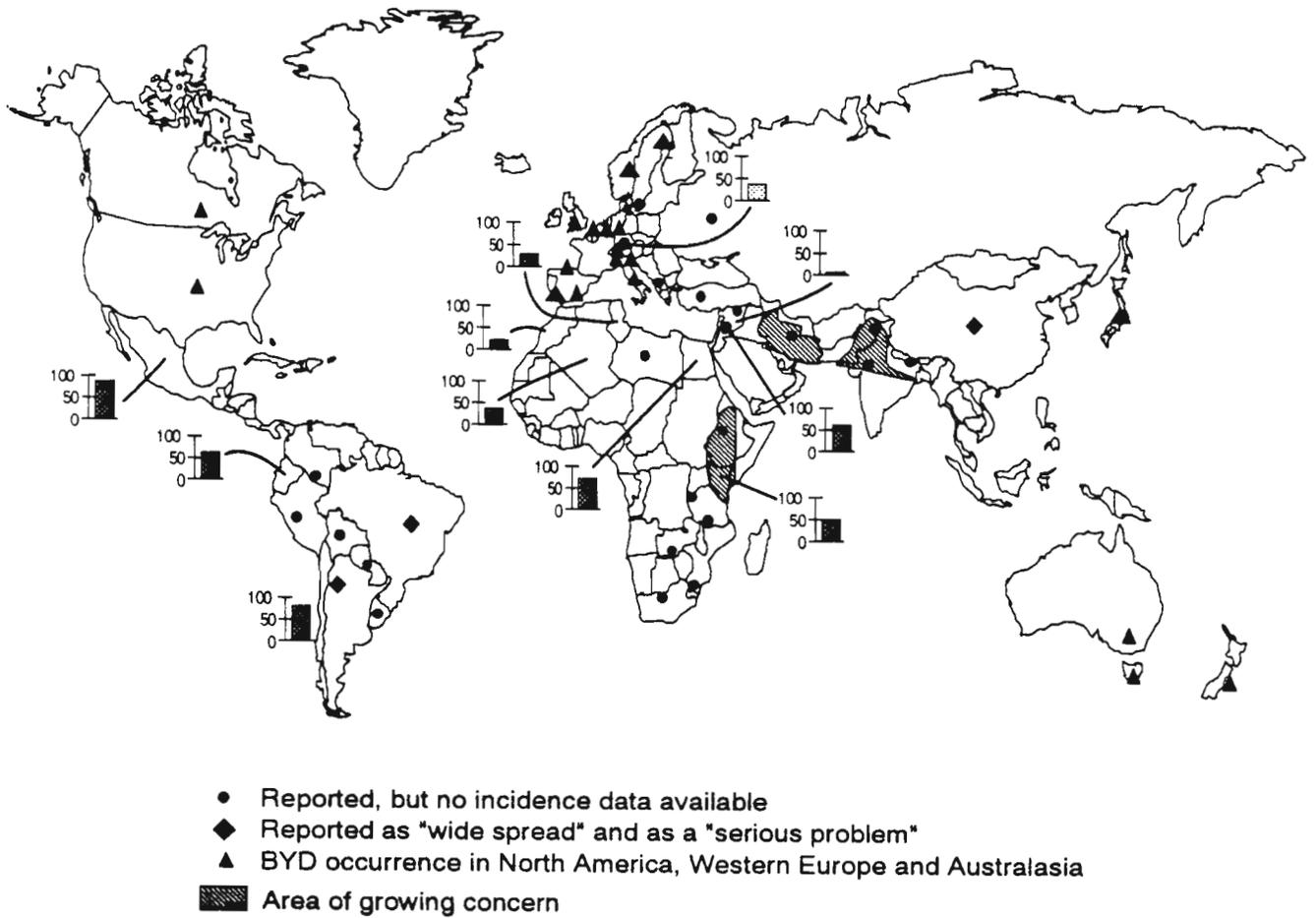


Figure 2. Worldwide presence and incidence of the barley yellow dwarf disease (BYD) in bread wheat. Compiled from Burnett (1990), Comeau and Makkouk (1992), and other references. Bar charts represent average incidence (percentage of plants infected under natural infection conditions) found in a survey conducted in a relevant production area in the respective country. For Hungary, incidence data were available only for barley.

techniques, including immunosorbent electron microscopy, RNA-hybridization with cDNA, dsRNA patterns (Gildow et al. 1983), and more recently by using virus group-specific primers and PCR (Robertson et al. 1991). Researchers are increasingly preferring these techniques. They allow for the direct detection of the viral RNA, which avoids the problems related to symptom evaluation. They may also be advantageous compared to ELISA, i.e., the detection of the viral coat protein by antibodies (specificity, sensitivity, targeting of determined sequences, etc.).

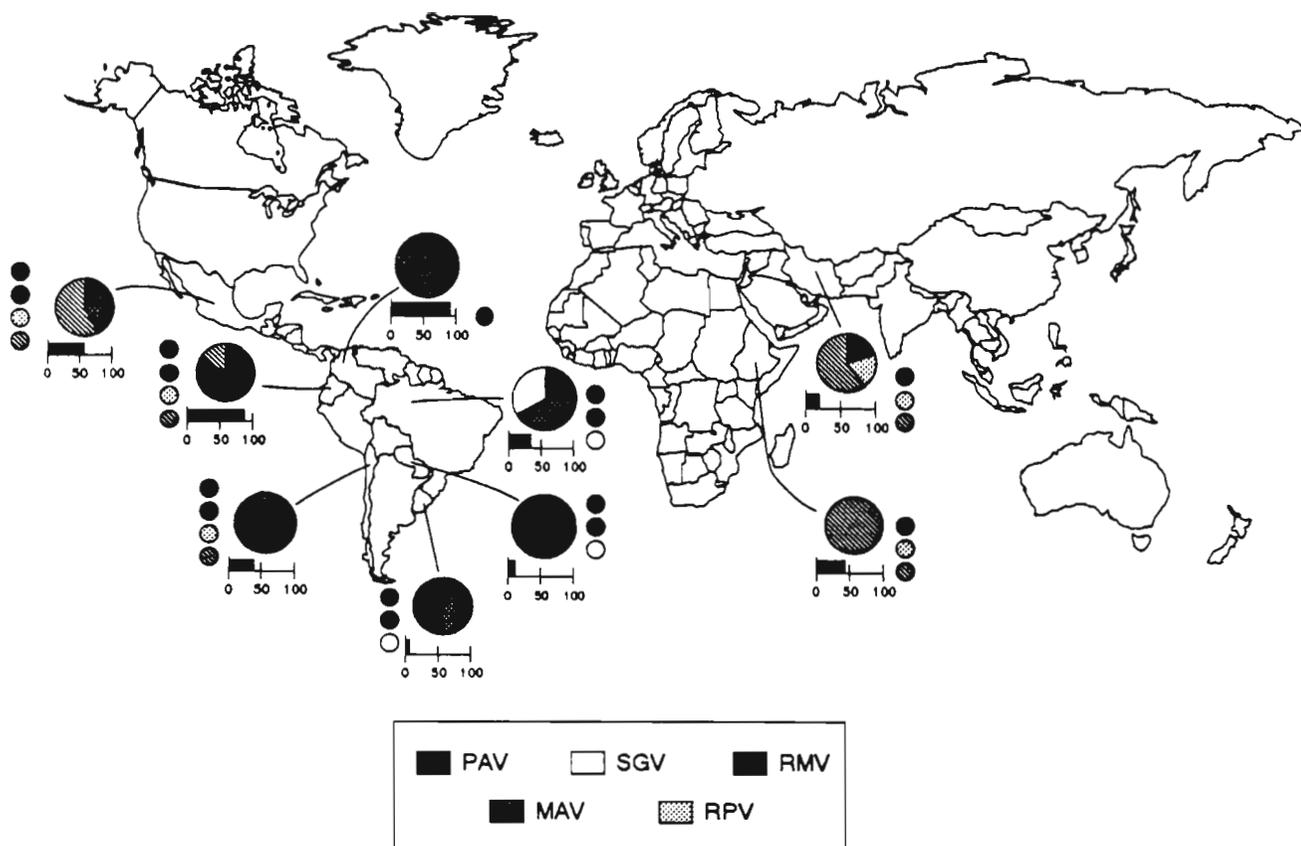


Figure 3. Occurrence of BYDVs in random samples of bread wheat and barley in CIMMYT nurseries during 1988-1990 (Webby et al. 1993).
Bar below each pie chart: % of BYDV-infected plants in random samples. Small circles: presence or absence of serotypes identified in samples with BYD symptoms.

The genomes of many plant viruses are currently mapped in numerous laboratories around the world by using molecular techniques. The RNA-sequence of particular isolates of BYDV strains has been analyzed (Miller et al. 1988, Rizzo et al. 1990, Vincent et al. 1991, Ueng et al. 1992).

Germplasm improvement--The ultimate overall goal of a germplasm improvement program related to a plant pathogen is the development of lines with a determined level of resistance to the pathogen with desired agronomic traits. In this Special Report, "resistance" will be used as defined by Cooper and Jones (1983)¹. Resistance is therefore distinguished from tolerance.

¹ Cooper and Jones' proposed terms for the various responses of plants to the challenge of virus inoculation and infection are now generally accepted by plant pathologist and virologists (Matthews 1991). For convenience, these terms are briefly described: Response of plants to inoculation: *infectible* (host plant can be infected)--*immune* (nonhost plant cannot be infected); Virus behavior in a plant: *susceptible* (virus readily infects and/or replicates and/or invades)--*resistant* (virus infection and/or replication and/or invasion restricted); disease response of plant: *sensitive* (plants react severely); *tolerant* (little or no apparent effect on the plants).

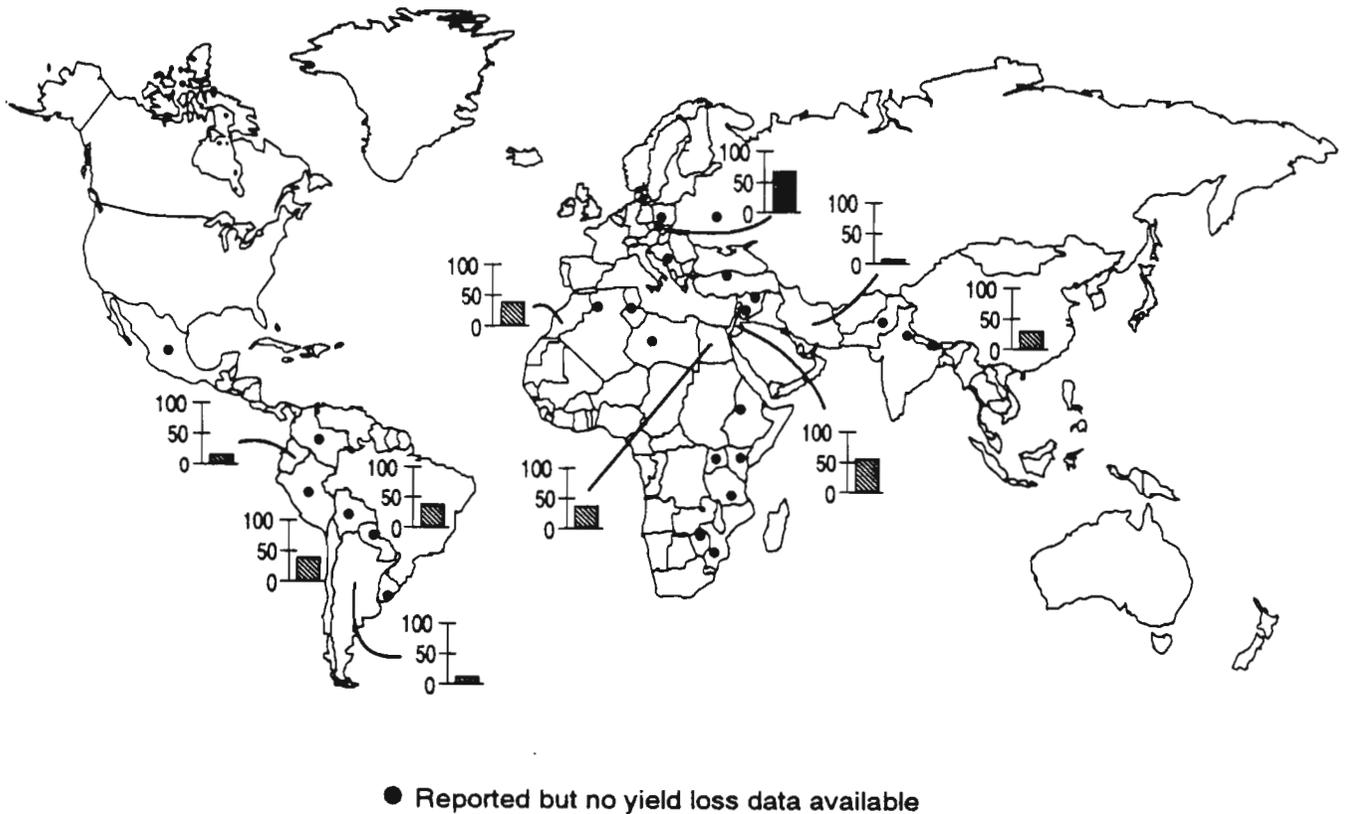


Figure 4. Average yield loss (%) of the wheat crop due to the barley yellow dwarf disease. Compiled from Burnett (1990), Comeau and Makkouk (1992), and other references. Bar charts represent average percent yield loss found in a survey conducted in a relevant production area in the respective country. For Hungary, data were available only for barley.

Sources of resistance. The knowledge of sources of resistance in bread wheat, barley, oats, and other Gramineae species has been reviewed recently (Burnett 1991). So far, no major gene has been identified in bread wheat that confers resistance to infection with BYDs and/or a reduction of their multiplication and/or invasion.

Sources that provide a certain level of quantitative resistance in winter wheat have been reported (Carrigan et al. 1981). However, it is now understood by many BYD researchers that the search for resistance genes within the genus *Triticum* yields variable results, as the lines showing less severe symptoms tend to be tolerant rather than resistant to the virus (Skaria et al. 1985). A tolerance gene, *Bdv1*, has been identified in CIMMYT germplasm (Singh et al. 1993). Tolerance could depend on genes that do not impede virus multiplication, which would have no effect on reducing the virus reservoir and might even increase it through increased biomass (Plourde et al. 1992).

Disomic bread wheat addition lines have been developed that carry the *Yd2* gene of barley (McGuire et al. 1990), a major gene that is incompletely dominant. The disomic addition of *Yd2* to wheat conferred, at best, a small improvement in resistance to BYD viruses in bread wheats. The authors, however, are optimistic that the expression of the gene can be improved in substitution and translocation lines.

High levels of resistance to BYD viruses (PAV and RMV) in *Agropyron* spp. were reported in the early 1980s (Sharma et al. 1984). Two octaploid derivatives (partial amphiploids; 56 chromosomes) of hybrids between *Thinopyrum intermedium* (Host) Barkworth and Dewey (syn. *Agropyron intermedium* (Host) P.B.) and hexaploid wheat, developed in the 1960s in China (Zhong 4 derived from a Chinese *Th. intermedium* accession) and France (TAF 46 derived from a *Th. intermedium* accession obtained from the University of Saskatoon; Cauderon 1966), as well as a series of addition and substitution lines with the prefixes 'TAF' and 'L' (42 or more chromosomes) were tested for resistance to BYD viruses in the 1980s (Brettell et al. 1988, Xin et al. 1988, Zhou et al. 1990) and proved promising, i.e., resistant. Experimental results strongly suggest that resistance(s) to BYDVs in Zhong lines is (are) chromosomal rather than cytoplasmic in origin (Xin et al. 1988) and that the resistance(s) is (are) carried on the chromosome complement derived from *Th. intermedium*. A major genetic resistance factor appears to be present on the chromosome pair from *Th. intermedium* in L1, homoeologous to the group 7 chromosomes of wheat (Brettell et al. 1988). L1 is a disomic addition (44 chromosomes) derived from TAF 46. Recent testing results make clear that this source of resistance may apply to a broad spectrum of BYDVs (Banks et al. 1992). The resistance derived from TAF 46 has been transferred to hexaploid wheat through recombination during cell culture (Griggs 1992).

Markers of resistance to BYDVs. Currently, the only marker available to assist selection is leaf tip necrosis, which helps selecting for tolerance to BYDVs (Singh et al. 1993).

A morphological marker (coleoptile anthocyanin pigmentation) associated with a *Thinopyrum* chromosome failed to associate with resistance to BYDVs in hexaploid wheat, derived from *Th. intermedium* and mentioned above (Banks et al. 1991). This can be explained since the genes for the pigmentation appear to be on the alpha-arm of the homoeologous chromosome of *Th. intermedium* to the group 7 chromosomes of wheat,

whereas the gene(s) for resistance to BYD viruses appear(s) to be located on the β -arm of this chromosome (Brettell et al. 1988).

Molecular probes are now being explored at CSIRO (Canberra Australia) for being used as markers, which are specific to alien genomes, for the recognition of an introgression from *Th. intermedium* (P.M. Banks, pers. com.)

Vector resistance. Mechanisms of resistance to the aphid vector of BYD viruses (antibiosis, antixenosis) could be a source of avoidance of infection with BYD viruses. Aphid failure on the phloem on some *Agropyron* spp. has been reported (Shukle et al. 1987).

Hydroxamic acids (Hx), especially DIMBOA, may play a role in protecting plants from aphids (Niemeyer 1991), but it is debatable whether they will work in nature since there is no good evidence of a relationship between Hx and resistance to aphids, especially in small grains and where concentrations of Hx are normally low (Plumb, pers. comm.). However, recent studies on the role of Hx in controlling aphids and BYDVs support a significant role of those compounds for aphid resistance in wheats (Niemeyer et al. 1992).

Epidemiology and pathosystem research--Technology is available for the investigation of particular components of the virus-vector-host plant pathosystem (virus detection, vector trapping, virus transmission indices, etc.). This technology was used for studying the epidemiology of BYDVs, particularly in Great Britain, USA, Canada, and Australia. However, in developing countries, data on the incidence of particular BYDVs, associated yield loss, and their epidemiology are still scarce.

Simulation models that predict the percentage of infected plants have been proposed (Morgan 1990). Model outputs are not yet considered to be accurate enough, but model development and validation are viewed as suitable exercises for highlighting "weaknesses in our knowledge of BYDV epidemiology that can be overcome by future research". These include crop attractiveness at different growth stages to alate aphids, the effect of low fluctuating temperatures on development and survival rates of apterous aphids, and the movement of these aphid morphs between plants.

The response of symptom expression and of resistance components operating in particular genotypes (such as virus multiplication) to contrasting environmental conditions (genotype x environment interactions) has not been profoundly characterized until now.

At present, quantitative population dynamics is being explored as a tool for the management of diseases caused by fungi (e.g., powdery mildew in Europe), especially in relation to the development of sustainable agro-ecosystems and an efficient use of germplasm. So far, similar approaches have not been undertaken for plant viruses even if they would seem appropriate particularly for viruses with a high degree of variability such as BYDVs.

Plant virology at agricultural research institutions in the 1980s--In the late 1970s and early 1980s, plant virology at agricultural research institutions was dominated by the development and application of diagnostic tools, such as serological techniques (ELISA and others), electron microscopy, etc., that were explored for the characterization and identification of viral pathogens and for their reliable routine diagnosis. Later in the last decade, new molecular techniques came into the picture that opened possibilities for the relatively easy analyses of the viral genome and more sensitive diagnoses.

Many resources have been allocated for engineering of plants with resistance to viruses (tobacco, tomato, papaya, potato, cucumber, etc.). Mainly viral genes, which encode for the coat protein, have been incorporated into the plant's DNA. This yielded, in certain cases, plants exhibiting various levels of resistance against virus multiplication. However, the protection provided by this approach appears to depend on the amount of sequence similarity between the engineered and the invading coat protein. Wheat transformation technology has been successfully developed (Vasil et al. 1992). For viral pathogens, including isolates with highly variable coat proteins (CP), CP-mediated resistance does not appear to be a promising approach for protecting against a broad range of isolates of the respective virus (Wilson 1993). Other approaches (antisense RNA-, satellite RNA-, defective RNA sequence-mediated resistance, etc.) might offer some more promising solutions, even if they might have other potential drawbacks (e.g., antisense RNA is produced in the nucleus while virus multiplication occurs in the cytoplasm).

Relatively few resources have been allocated to the research of the ecology of a plant virus and of its epidemiology in the last decade. Serology and molecular analysis have opened new possibilities for pathogen diagnosis and research in pathogen ecology and epidemiology, and they have tremendously improved our understanding of virus architecture and of the composition, regulation, and expression of the viral genome. These techniques now also allow for the processing of numerous samples within a short time and

for the detection of viruses with a high sensitivity--both requirements for the study of populations of pathogens and for mass screening for germplasm improvement programs.

CIMMYT

Funding and overall goals--Research on BYD viruses has had restricted core funds from the Dipartimento Cooperazione Allo Sviluppo (DCAS) of the Republic of Italy since late 1984 when DCAS and CIMMYT signed the contract "Technical Assistance Grant for an International Integrated Pest Management Project for the Control of Barley Yellow Dwarf Virus Disease of Cereal Crops". The agreement included the "back-transfer" of a percentage of the granted funding to cooperating Italian institutions. The Rockefeller Foundation (1984) and USAID (1985-1988) provided some additional indirect support, which was channeled through the University of California at Davis to develop germplasm that is resistant/tolerant to BYD viruses.

CIMMYT's contract with DCAS was considered as a "cooperative effort, managed and coordinated by CIMMYT, between institutions in developed and developing nations directed toward the transfer of improved technology, knowledge, and expertise from developed countries to those low-income developing countries where BYDV is a problem" (CIMMYT 1984). The project aimed to reduce losses caused by the virus disease by supporting the transfer of technology from developed country institutions (including Italian institutions directly funded by the grant). The effort was to take place over a five-year period. A project extension at the end of 1988 was to strengthen the international network of researchers--established during the first phase of the project--familiar with BYD viruses (CIMMYT 1988). To successfully transfer the technology developed by the project to developing countries, a number of interrelated and complementary activities were envisioned, such as:

- Strengthening institutional relationships among developed and developing country research institutions;
- Offering training opportunities for national program scientists in developing countries where BYDVs cause significant economic losses in production;
- Extensively screening germplasm to develop entries resistant/tolerant to BYDVs and delivering this germplasm to national program collaborators (CIMMYT 1988).

Most important program accomplishments--Major accomplishments of the project have included the following.

Networking and training. The project collaborated with several national programs in developing countries--see section on collaborative projects with national agricultural research systems (NARSs) in developing countries. The project also established relationships with other small grain research programs and laboratories that are independently funded. These included:

- Agriculture Canada, Ste-Foy, Quebec, Canada (A. Comeau), which collaborated intensely in testing, developing, and exchanging germplasm;
- University of Illinois, Illinois, USA (C.J. D'Arcy);
- Crop Research Division, New Zealand (J.M. McEwan);
- Dept. of Agriculture, Western Australia, Australia (R. Wilson);
- Plant Research Institute, Victoria, Australia (R. Sward);
- MAFF Laboratory, Harpenden-Herts, UK (I. Barker);
- CIDA Las Torres, Sevilla, Spain (F. Montes);
- Madrid, Spain (J. Hernando);
- Lerida, Spain (C. Royo);
- INRA/MIAC, Settat, Morocco (M. El Yamani); and
- ICARDA, Aleppo, Syria (K. Makkouk).

Italian institutions, which have benefited directly from the CIMMYT/DCAS-contract, and their principal research agendas included:

- University of Udine, Istituto di Difesa delle Piante, Udine, Italy (E. Refatti: project coordinator for Italian institutions; R. Osler, N. Loi): studies on virus-vector relationships, the role of maize in BYD epidemiology, a particular RMV isolate, maize dwarf mosaic virus (MDMV), and combined infections with MDMV and BYD viruses in maize, vector dynamics.
- Consiglio Nazionale delle Ricerche, Istituto di Fitovirologia Applicata, Torino, Italy (M. Conti): studies on vector dynamics, strain infectivity, antiserum production, BYDV-0C isolate characterization (Piedmont region).
- University of Milan, Istituto di Patologia Vegetale, Milan, Italy (G. Belli): RGV-76 purification (BYDV isolate, rice "giallum" virus), antiserum

production, studying the role of different cereals in BYDV epidemiology in the Po Valley.

- Università Cattolica del Sacro Cuore, Facoltà di Agraria, Piacenza, Italy (C. Lorenzoni): screening and breeding for resistance (barley, maize, wheat), incorporation of the Yd2 gene into barleys, studying yield losses due to BYD viruses in cereals in Italy.
- Università degli Studi della Tuscia, Dipartimento di Agrobiologia e Agrochimica, Viterbo, Italy (E. Porceddu, C. de Pace): studying vector dynamics of *Rhopalosiphum padi* (L.) and its predators and parasitoids, germplasm survey for tolerance, studying the epidemiology of PAV isolate in Viterbo area, testing hybridization methods (cooperation Udine group) for survey work on Triticeae accessions.

Some laboratories and small grain programs were financially supported by the project for their active collaboration in offering diagnostic services, developing germplasm or educating students. These institutions were:

- Purdue University, USA (R. Lister): development of antisera, sample testing, and consultancy travel.
- Rothamsted Experimental Station (R. Plumb): sample testing, Ph.D. thesis guidance, consultancy travel.
- University of California at Davis, USA (C. Qualset): germplasm development and exchange, M.Sc. thesis guidance, consultancy travel.

The partners of CIMMYT's BYD network were not necessarily interlinked, and were treated primarily on a case-by-case basis. Efforts were funneled through CIMMYT's BYD pathologist who, as representing CIMMYT, had the responsibility for research coordination within the network.

Several scientists have visited CIMMYT with the support of the DCAS/CIMMYT-project and acted as consultants. Training in BYD viruses has been part of CIMMYT's annual wheat improvement training course (breeding and pathology). Several participants from developing countries have been supported.

A workshop on BYD viruses was organized in Udine, Italy, July 6-11, 1987. Numerous scientists from developed and developing countries attended. The proceedings of the

conference (Burnett 1990) include the papers and posters presented on world situation, virology, ecology and epidemiology, and control.

Germplasm improvement and virological research: facilities, activities and findings.

CIMMYT's past research projects on BYDVs are documented and reviewed in the *Research Project Updates and Descriptions of New Projects for the CIMMYT Wheat Program* (Fischer and Hettel 1991, 1992, 1993). The state of the art of research on BYDVs and the related established facilities are summarized in the following.

In the area of infrastructure and research report:

- ELISA facilities are available now at CIMMYT with a maximum capacity of 1600 samples processed per week if two persons work full-time in the laboratory.
- BYDVs from Mexico have been isolated and were identified and biologically characterized as PAV, MAV, RPV, and RMV-like strains. Isolates are maintained *in-vivo* (except SGV) with aphid species which had been identified as the most efficient vector species of the respective serotype in the valley of Mexico. SGV-like isolates have been detected serologically.
- Aphid-rearing facilities exist for field and greenhouse infestation of plants with aphids. Stock colonies of *Diuraphis noxia* (Morvilko), *Diuraphis mexicana* (Baker), *Metopolophium dirhodum* (Walker), *Rhopalosiphum maidis*, *R. padi* (L.) (Fitch), *Sitobion avenae* (Fabricius), *Sipha flava* (Forbes), and *Schizaphis graminum* (Rondani) are maintained.

In the area of diagnosis:

- The incidence of five serotypes of BYDVs was determined from random and symptomatic collections in cereal nurseries in South America from 1988 to 1990 by testing over 900 samples at Purdue University. During the same time, more than 1100 samples were tested from miscellaneous collections from Latin America and Old World countries (Webby et al. 1992) and significant differences were found for the serotype prevalence in different zones.
- The seasonal occurrence of BYD viruses in Toluca was studied to use CIMMYT stations more efficiently as sites for germplasm selection under natural infection (Ranieri et al. 1993). The results suggest that winter plantings

in Toluca normally display the most severe symptoms caused by BYDVs. Apparently, Mex-MAV isolates are the most prevalent. As a consequence of these experiments, studies on cross-protection were initiated to determine the degree that natural infection of a particular serotype might protect against the infection with another (Ranieri et al. 1992). It appears that Mex-MAV protects significantly against infection with Mex-PAV, which is normally the more severe strain.

In the area of germplasm development:

- More than 30,000 cereal lines have been screened in the field under natural BYDV epidemics in Mexico, mostly at CIMMYT's station in Toluca. To a certain extent, bread wheat lines have been considered resistant to BYDVs, based on visual scoring and their performance in screening nurseries (Burnett et al. 1991). It was found that the lines selected with these criteria are tolerant rather than resistant. The tolerance was identified by quantifying yield losses caused by BYDVs and by assessing relative virus titres in infected plants by means of ELISA (Ranieri et al. 1991). These studies documented that CIMMYT genotypes confer a wide range of different plant responses to BYDVs infection. According to these results, lines with low symptom scores might exhibit even higher yield reduction than lines with higher symptom scores. Therefore, ranking of lines according to yield losses due to BYDVs is not always consistent with the ranking according symptom expression severity (Mezzalama et al. 1991a).

- Four different sets of spring bread wheats (*Triticum aestivum* L.), three different sets of triticales (*X Triticosecale* Wittmack) and durum wheats (*Triticum durum* L.), and 10 different sets of barleys (*Hordeum vulgare* L.) were distributed as international BYDV screening nurseries (BYDSNs) to numerous countries (BYDSNs 1-7 for bread wheat, durum wheat and triticales; BYDSN 1-10 for barley). No acceptable sources of resistance in durum wheat have been identified. The *Yd2* gene in barley was found to be beneficial to yield and also to reduce titres significantly of determined serotypes (Ranieri et al. 1991). It was generally observed that triticales perform well under natural epidemics of BYD viruses. The nursery material also includes bread wheat genotypes with low visual disease scores, but they are probably tolerant and not resistant (see below). One major gene conferring tolerance--a characteristic of

the cultivar Anza--was identified and named *Bdv1* (CIMMYT 1992, Mezzalama et al. 1991b, Singh et al. 1993). Other genetic studies found dominance and quantitative inheritance for tolerance in crosses using Anza (Qualset et al. 1973), suggesting the presence of further tolerance factors. So far, no resistance genes have been identified in the bread wheats.

Other miscellaneous research:

- A high variation of screening resulting across sites has been noted (Burnett et al. 1990). This suggests a strong virus x host genotype x environment interaction that makes the interpretation of BYDSN data difficult. Correlations among genotype responses to infection with BYD viruses over environments have been explored in a preliminary manner by using nonparametric methods (Raun et al. 1990).
- Samples of plants, which by symptoms were suspected to be BYDV-infected, did not react with antibodies produced against North American, European or Mexican isolates (e.g., isolate from Ciudad Obregon--H. Vivar, pers. comm.; Turkey--E.E. Saari, pers. comm.). Furthermore, strains that await identification may cause these symptoms. Also, there is considerable genomic variability between different isolates of equally classified BYDVs, i.e., there are different PAV, MAV, RPV, etc; (W.A. Miller, pers. comm.; A. Chalhoub, pers. comm.).
- CIMMYT's research on Russian wheat aphid (RWA) (*Diuraphis noxia*) has been supported, in part, by the BYD Section. Transmission tests with Mexican isolates of BYDVs were unsuccessful. Methodologies of investigating tolerance, antibiosis, and antixenosis to RWA have been tested and established in the field and in the greenhouse (Robinson 1992, 1994; Robinson et al. 1992). Several sources of antibiosis and tolerance and some antixenosis have been identified in CIMMYT small grain accessions (in barleys and *Triticum turgidum* L. var. *dicoccum* Schrank). The genetics of resistance are being analyzed as part of CIMMYT's prebreeding strategies (Burnett et al. 1991). Molecular markers have recently been identified for a gene that confers resistance to RWA in barley (Dorregaray 1992). The resistance to RWA is not necessarily correlated with resistance to other aphid species (Frank et al. 1989; J. Robinson, pers. comm.). RAPD markers proved to be a sensitive tool for monitoring genetic changes in aphid populations. Aphid colonies of different

species and from different origins were successfully discriminated at CIMMYT by molecular fingerprints produced by RAPD marker and PCR techniques (Robinson et al. 1993). Furthermore, aphid biotypes have been successfully identified by RFLP markers (Birch et al. 1992).

Collaborative projects with NARSs in developing countries after 1985--The overall aim of the collaborative projects was to assist programs with partial, not total, funding of a project. One scientist has been supported for M.Sc. studies (from Ecuador in the USA), one for Ph.D. studies (from Chile in England), and two are presently being supported to do their Ph.D. (one from Ecuador in the USA and one from Kenya in England). Several Mexican students were funded by the program to do their M.Sc. on BYDVs.

Principal collaborative projects existed with NARSs in the following countries:

- Argentina: aphid house repair, 1986 (Eng. A.E. de Biasi, INTA, Castelar); *Project*: identification and epidemiology of virus disease in wheat and winter cereal crops, 1990-1991 (G. Truol, I. Laguna, S. Nome: INTA; R. Ascietto: Univ. Córdoba; P. Rodriguez P., CONICET, Córdoba); *Objectives*: characterization of virus strains, economic importance (wheat and winter cereal crops), adjustment of serological techniques and cDNA-probe use, incidence studies, virus purification, antibody production, study virus reservoirs, screening for resistance; *Budget positions*: Per diems, travel, subsistence, and supplies.
- Chile: INIA/CIMMYT project, 1986-1988 (Dr. I. Ramirez, INIA, Santiago); *Objectives*: study virus incidence and vector distribution, yield losses, epidemiology (vector population dynamics, virus strains, and reservoirs), germplasm evaluation, integrated control (selective insecticides, parasitoids, and predators). Activities are well documented in INIA reports. Study leaves of Eng. G. Herrera M. (Ph.D. program in virus epidemiology, Imperial College, London, Dr. R. Plumb), returned end of 1989, and Eng. C. Quiroz (entomologist); *Budget positions*: Salaries and per diems, travel, subsistence, supplies.
- China: CAAS/CIMMYT contract, two phases, 1986-1992 (Prof. G.H. Zhou, CAAS Inst. Plant Protection, Beijing). *Objectives*: Black light lamp aphid trapping, develop cDNA probes for virus CAAS Inst. Plant Protection, Beijing detection in single aphids, develop monoclonal antibodies for GPV-BYDV,

look for sources of resistance by screening grasses in greenhouse and field;
Budget positions: Per diems, supplies, subsistence, and travel.

- Colombia: Project started in 1990 (three years, partially approved and funded; Dr. R. Britto M., ICA Tibaitata, Bogotá). *Objectives*: Development of wheat and barley lines that are BYDV and Nariño dwarf resistant, pathogen identification, transmission potential of natural populations of *Cicadulina pastusae* (Nariño dwarf vector); *Budget positions*: Aphid greenhouse, subsistence and supplies.
- Ecuador: Used as hot spot screening site; INIAP/CIMMYT project, 1987-1989 (Dr. J. Tola/Ing. J. Urbano). *Objectives*: identify sources for resistance and tolerance, increase resistance level in germplasm, vector and virulence/resistance studies. M.Sc. study leave: O. Chicaiza (breeding/virology), returned 1990, now on Ph. D. studies in the USA (barley/leaf rust); *Budget positions*: Aphid greenhouse, labor, travel, meetings, supplies.
- Kenya: Collaboration started in 1987 (Dr. J.K. Wanjama, Mrs. A. Wangai, NPBR, Njoro). Yield loss and epidemiology, vector dynamics. Short-term training at Rothamsted Experimental Station (Dr. R. Plumb, GB) for A. Wangai, Ph. D. study leave arranged for 1993 (Reading/Rothamsted Experimental Station, Dr. H.F. van Emden/Dr. R. Plumb).
- Zimbabwe: 1987-1989 (Mr. A. Gubba). *Objectives*: BYD incidence in cereals including barley, vector identification; *Budget positions*: travel, subsistence, supplies.

Institutional setting of CIMMYT's BYD research

The second phase of the CIMMYT/DCAS was concluded in 1992, but Italy continued funding through 1993. No formal proposals presently exist for a further extension of the project, but there is some probability of project extension with reduced funding and possibly the hiring of a postdoctoral fellow. The collaborators from the past, in developing as well as developed countries, are not formally bound to the CIMMYT program. However, BYD has been considered by the TAC of the CGIAR as an essential activity of CIMMYT, implying that the center should allocate funds to the program.

A core scientist headed BYD research until he left in August 1991. Subsequently, this position was eliminated (but reinstated briefly during May-October 1994). The center group that works on BYD included one associate scientist, who became a senior scientist in May

1994 (L. Bertschinger, head of the BYD Section between June 1992 and October 1994); three permanent technicians (field and laboratory); and one or two temporary field workers. One associate scientist (J. Robinson) was working on RWA and other cereal aphids until he left in October 1992. He provided permanent entomological inputs that were essential for the program's work on virus transmission studies, screening procedures for aphid resistance, and vector population studies. This position was not refilled.

The BYD Section benefited from direct access to CIMMYT's facilities, allowing for a rapid incorporation of identified, desired traits into advanced germplasm, an exceptionally rapid multiplication of germplasm material, multilocation testing, and good facilities for the development and application of serological and molecular techniques.

BYD Research Strategy for 1994-97

In this section, overall goals are outlined. Research areas and immediate priorities are identified for the next three years. Staffing is discussed and operational guidelines are given. Particular projects will be developed based on these goals. They are documented in the Wheat Program's Annual Research Project Updates and Descriptions (Fischer and Hettel 1991, 1992, 1993). Active projects as of October 1994 are listed in **Appendix 2**. Interactions with other programs and NARSs will be developed if appropriate according to the guidelines discussed below.

The overall goals of BYD research

The principal goal of CIMMYT's BYD research program is development of resistant/tolerant germplasm. However, it is generally understood that a sound knowledge of a pathogen's epidemiology and ecology and of the pathogen's interaction with the host plant and its environment is essential for efficient allocation of germplasm to contrasting environments. CIMMYT should conduct research in the following areas if it has a comparative advantage over other institutions and if results can be expected more rapidly by doing the work at CIMMYT than at other institutions:

- Identify and characterize sources of resistance and tolerance (*sensu* Cooper and Jones 1983), prioritizing the search for resistance, especially in wild and cultivated relatives, and make them available for breeding of primarily advanced bread wheat germplasm.

- Support breeding for advanced germplasm destined for the developing world with resistance and/or tolerance to BYDVs.
- Make these resistance and tolerance sources available to small grain improvement programs in developing countries, especially those interested in BYDVs.
- Strengthen capacity of developing countries NARSs in the assessment of BYD in their respective agro-ecozones and in approaching methods of BYD control.

Areas of CIMMYT's research and support

The research areas are specified including the approximate percentage of the overall time, which the BYD staff should allocate to the respective research activities. A total of 100% is reached with training activities (10%) and general expertise provided on viruses and aphids to the Wheat Program and related problems as opportunities arise (10%).

Diagnosis--This area makes up 20%.

- Worldwide mapping and monitoring of virus variability, virus prevalence, and incidence and potential yield losses, prioritizing first bread wheat and second barley. Monitoring vector variability in terms of biotypic characteristics and virus transmission efficiency might become important as well, especially if monitoring tools become available.
- Evaluating, developing, and applying modern diagnostic methods that facilitate this assessment and develop them further that they may be used by NARSs scientists.

Support of breeders in obtaining resistance and/or tolerance to BYDVs--This area makes up 25%.

- Establishing and managing protocols and facilities for routine testing for resistance and tolerance to BYDVs provide leadership and expertise to the department in handling BYDVs in their field plots.

Identification and analysis of the inheritance of genes of resistance and tolerance to BYDVs--This area makes up 20%.

- Identifying and characterizing sources of resistance and tolerance components to BYDVs (e.g., resistance to virus infection, to virus multiplication, to aphid colonization, low yield response to high virus titres, etc.).
- Generating knowledge that facilitates a rapid incorporation of identified sources of resistance and tolerance components into advanced material (inheritance analysis, identification of genes).

Pathosystem research--This area makes up 15%.

- Identifying and characterizing viral pathogens of small grain cereals and their respective vectors.
- Studying and characterizing the pathogen x host genotype x environment interaction.
- Studying the relevance of the different components and mechanisms of the virus-vector-plant pathosystem for the epidemiology of BYD viruses in contrasting agro-ecological zones.
- Evaluating strategies of disease management for their effectiveness in controlling BYD viruses in their respective agro-ecological zones.
- Studying the relevance of BYD reservoirs in small grain crops and other Gramineae species for BYD epiphytotics in diverse cropping systems, and the temporal and spatial aspects of epiphytotics.
- Evaluating, and adapting tools that might be suitable for monitoring vector variability in terms of biotypic characteristics of an aphid species, and of those related to virus transmission.

Priorities for the 1994-97 period

The quantitative assessment of the importance of a pathogen, involving its reliable diagnosis, studying its prevalence and incidence, related agronomic and economic damage, and pathogen dynamics, must be among the first steps in any disease-related crop improvement program. The worldwide mapping of strain prevalence and the relevance of this information for farmers in the respective zones are crucial for obtaining material with durable resistance and for an efficient and sustainable management of the germplasm. CIMMYT has already generated data that represents a significant step forward in the worldwide diagnosis and mapping of BYD (Webby et al. 1992). However, the data need to be further compiled, compared with data from other collaborators, and carefully analyzed in relation to their relevance for particular agro-ecological zones. Further diagnosis is

necessary in areas that have not been covered so far. This diagnosis also needs to make certain that the data are representative for the *target environments* that cover principal production areas and that may benefit from germplasm, resistant to zone-specific BYDVs.

New diagnostic tools (e.g., probes for the detection of specific nucleic acid sequences), need to be evaluated vs. the use of an antibody panel for ELISA for suitability for worldwide assessment of BYD incidence and variability. If necessary, new tools and protocols need to be developed for the BYD diagnosis and the mapping initiative, as well as for an effective germplasm improvement program. The involvement of other institutions in industrialized countries needs to be evaluated in this respect.

Germplasm of wild and cultivated relatives needs to be tested for resistance (*sensu* Cooper et al. 1983). The donor species of the genome of hexaploid wheats should receive priority. The resistance in this germplasm needs to be characterized (immunity, resistance to infection, multiplication, etc.). Sources of resistance need to be incorporated into *susceptible, sensitive* advanced germplasm. Sources to be transferred have to be prioritized according to diagnostic (virus strain incidence in different agro-ecozones) and epidemiological criteria (relevance of resistance components for epiphytotic, yield loss). Among several approaches for the transfer, molecular markers for the components of virus and aphid resistance may be the method of choice in case there is a comparative advantage of marker assisted selection vs. other selection protocols. Developing mapping populations at the level of the related species of hexaploid wheat may be one approach for marker identification and subsequent efficient transfer of the desired trait to advanced material.

Lines, which are believed to carry *Th. intermedium*-derived resistance (56, 44, and 42 chromosomes), are in CIMMYT's germplasm bank. The type of resistance, which this material carries, needs to be characterized for several BYDVs, and if desirable, incorporated into advanced material.

Screening protocols (field, greenhouse) need to be constantly reviewed for making them more effective in identifying sources of resistance and tolerance.

Once new entries with sources of tolerance and resistance to BYDVs have been identified, a new BYDSN may be assembled and made available.

Possibilities are to be explored on how to facilitate meaningful comparison of symptomatic screening data across contrasting environments. Methods may be explored that facilitate the analysis of scores across years and environments (e.g., score correction by accounting for titre, symptom expression, plant age, genotype, and environment interactions).

Staffing

The actual situation related to BYD staffing has been described above. The loss of both the full-time BYD head and the entomologist might cripple BYD research at CIMMYT.

Perhaps a postdoctoral fellow could be hired to assume some of the duties of L. Bertschinger. To replace J. Robinson, a scientist, who can dedicate time principally to applied entomology (agricultural entomologist preferred) should be hired. This would ensure adequate management of the rearing facilities in the long-term and could also provide leadership in RWA and other aphid resistance research. Ways of ensuring continuity in this respect need to be explored.

Operational avenues

Locations--The following activities should be developed at CIMMYT's headquarters:

- Germplasm development and support to breeding, including identification, and characterization of different resistance/tolerance components, inheritance studies, etc. As much as possible, confounding effects of the environment should be avoided. Therefore, for each nursery to be tested, a balance needs to be found between the amount of lines to be tested and the uniformity the protocol applied may provide given the available resources (greenhouse, growth chamber, controlled infections in the field, replicates, etc.).
- Evaluation, development and application of diagnostic tools that facilitate virus detection.
- Virus testing for mapping and monitoring purposes.

Activities at CIMMYT headquarters and in collaboration with CIMMYT's regional offices and NARSs:

- Studies in the field with germplasm with previous characterization of its resistance/tolerance components and attributes. Experimental sites have to represent the target environments of the program that had been selected according diagnostic research (see 1994-97 priorities). Careful selection of

these sites is intended to assure that expected results are relevant to the resistance breeding directed onto the principle target environments and hence for the potential clients of improved germplasm.

Activities related to other research areas (pathosystem research, etc.) may be developed at headquarters or in outreach depending on the comparative advantage related to the particular research objective.

Program implementation--In the long-term, the program needs to focus on:

- Establishing and maintaining a strong relation to CIMMYT's breeding programs for ensuring efficient and effective exploitation and improvement of germplasm.
- Strengthening NARSs in hot spot areas to assess the problem related to BYDVs and to develop solutions to the problem.
- Assisting collaborating institutions in assuming responsibility for essential parts of any of the Section's activities, if it is judged to be a comparative advantage. This needs to be evaluated on a case-by-case basis. We may have joint BYDV research programs or responsibility passed to specialists in diagnosis, germplasm testing, and pathosystem research in industrialized and developing countries. The criteria used may be how this affects: 1) acceleration of germplasm improvement and the world-wide assessment of the prevalence and severity of problems caused by BYDVs, 2) contribution to the availability of germplasm with a high degree of genetic variability related to the response to BYDVs, 3) contribution to efficient resources allocation, 4) facilitation of information exchange, and 5) support in institution building in developing countries. Collaborations, which have been developed between CIMMYT and other institutions, may be continued or discontinued in view of these priorities.
- Economics: The program should envisage a good balance between the priorities and the investments for the respective project/activity. Approaches are to be explored, which facilitate decision making in this respect. Economical aspects related to specific resistance/tolerance components may be documented and studied, allowing for a holistic evaluation of the crop improvement attempted.

The above-mentioned avenues are in line with CIMMYT's operational strategies related to germplasm improvement, economic analysis of research priorities and impacts (CIMMYT 1989).

Information exchange--In the past, the program funded the BYD Newsletter (BYDNL) that served as a nonreviewed publication that facilitated information exchange among BYD researchers in developed and developing countries, free of cost, once a year. The mailing list of the BYDNL No. 5 (Sept. 1994) included more than 160 researchers of which a majority were from developing countries. Budgets in agricultural research are tight worldwide. So, the purpose and usefulness of the NL was reviewed through a questionnaire sent to cooperators in 1994. Most responses urged that the BYDNL be continued--hence issue No. 5 was released in September 1994. As a way to fund the BYDNL, subscription fees are now being charged to cooperators in developed countries. BYDNL No. 6 will be published in 1995 with assistance from collaborators in the U.S. Other approaches for information exchange should be evaluated (e.g., e-mail bulletin board, news groups, etc.).

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Appendix 1. Brief Summary of BYD Research Achievements at CIMMYT, 1985-1991

- Screened of over 30 000 cereal lines for resistance/tolerance to BYD viruses mostly under natural infection conditions (predominance: MAV-Mex).
- Identified a gene for tolerance to BYDV.
- Distributed BYD screening nurseries (4 bread wheat sets, 3 triticale and durum wheat sets, 10 barley sets) to national programs. A high variation of screening resulting across sites has been noted.
- Studied the epidemiology of BYDVs and population dynamics of their aphid vectors in Mexico (MAV-Mex appear to be predominant in the Valley of Mexico).
- Assisted in surveying BYDV serotypes from South America and Africa.
- Studied the genetics of resistance to BYDVs in wheat.
- Assessed yield losses due to BYD in wheat and barley, and studied its relation with virus titres as measured by ELISA. Demonstrated that ranking of lines according to yield losses due to BYD viruses is not necessarily consistent with the ranking according severity of symptom expression.
- Assessed the mechanism of resistance to BYDVs in selected cereal lines.
- Sponsored the training of three graduate students.
- Funded research on BYDVs in selected national; programs (Argentina, Chile, China, Colombia, Ecuador, Kenya, and Zimbabwe).
- Assisted in teaching CIMMYT trainees in Mexico and instructed in country workshops.
- Organized and international conference on BYD, edited and published proceedings.
- Produced four issues of an annual BYD Newsletter.

- Fostered an active network of BYD workers.

- Russian wheat aphid research:
 - Unsuccessful transmission tests with Mexican isolates of BYDVs.
 - Established methodologies for testing tolerance, antibiosis, and antixenosis to cereal aphids in the field or in the greenhouse.
 - Identified sources of antibiosis and tolerance and also some of antixenosis in barleys, dicoccums and Turkish wheats, the latter two as part of CIMMYT's prebreeding strategies (Burnett 1991).
 - Fingerprinting aphid colonies of different species from different origins by RAPD marker and PCR techniques.

Appendix 2. CIMMYT BYD Projects and Activities, with Publication Record, through September 1994

Projects

Diagnosis (20% of research time)

Project No. CPBD8801: Survey of barley yellow dwarf viruses (BYDVs) serotypes in cereal nurseries in Latin America, Asia, and Africa. Continued the monitoring project for assessing the variability of BYD viruses in developing countries (micro-scale temporal monitoring, macro-scale spatial monitoring).

Presently: 1) samples accumulating from Mexico, Ecuador, Iran, Pakistan, and other zones, and 2) a set of contrasting antibodies for simultaneous testing. General monitoring by testing samples that were sent by collaborators (mainly few samples per location). More extensive testing was done on samples from Ecuador (with INIAP), Iran (Agricultural Research Center of Mazandaran, Sari), Kenya (with Rothamsted Experimental Station and KARI), Mexico (CIMMYT), Pakistan (NARC), Turkey (Turkish Winter Wheat Program, CIMMYT, ICARDA). Lack of reaction with a number of ant-BYDV antibodies of samples exhibiting typical BYD symptoms in Turkey confirmed by tests performed at Purdue University (P.

McGrath). **Publications:** 1) Bashir, M., L. Bertschinger, N.S. Kisana, M.Y. Mujahid, and N.I. Hashmi. 1994. Detection of five barley yellow dwarf luteovirus serotypes in Pakistan. BYD Newsletter 5. 2) Bashir, M., L. Bertschinger, N.S. Kisana, M.Y. Mujahid, and N.I. Hashmi. 1994. Detection of five barley yellow dwarf luteovirus serotypes in Pakistan. Plant Pathology, submitted. 3) Henry, M. Macharia, L. Bertschinger, J.K. Wanjama, and R.T. Plumb. 1994. Characterization of BYDV isolates occurring in Kenya. BYD Newsletter 5.

Support of the Germplasm Improvement Subprogram in breeding for resistance and/or tolerance to BYDVs (25% of research time)

Project No. CPBD9206: Testing of germplasm for tolerance and resistance to BYD viruses. Testing protocol for tolerance under field conditions with artificial infection (PAV-Mex, and RPV-Mex) and a particular field design facilitating assessment of sensitivity to BYDVs established. Evaluated more than 3000 bread wheats, 100 durum wheats, 500 triticales, and 350 barley for tolerance to BYDVs. Genome donor species of hexaploid wheat tested. Evaluated 509 entries of *Triticum dicoccum*, 45 entries of *Triticum monococcum* L., and 52 entries of *Aegilops squarrosa* Tausch. Data obtained have been given back to the breeders. **Publication:** Bertschinger, L. 1994. New procedures for the effective field screening of cereals for symptomatic tolerance to barley yellow dwarf luteoviruses. BYD Newsletter 5.

Identification and analysis of the inheritance of genes of resistance and tolerance to BYDVs (20% of research time)

Project No. CPBD8501: Crosses made between tolerant and sensitive bread wheat lines (parents pretested and purified), and resistant (see project CPBD9205) and susceptible (and sensitive) lines. In the tolerant x sensitive crosses, a set of Filin lines is included that could be near isogenic for the tolerance genes.

Project No. CPBD9201: Identification of sources of resistance in selected germplasm lines of spring bread wheat, spring barley, triticales and wide cross material. Protocol for characterizing germplasm for components of resistance in the greenhouse established; capacity: 45 entries tested for four serotypes per month. More than 1500 genotypes tested. A paper on tolerant *Triticum dicoccums* is being written up. **Publication:** Bertschinger, L., and A. Mujeeb-Kazi. 1994. A search for new sources of resistance to barley yellow dwarf luteoviruses in bread wheat background. BYD Newsletter 5.

Project No. CPBD9205: Characterization, improvement and genetic analysis of hexaploid wheat with introgression(s) from *Thinopyrum intermedium* in relation to its reaction to BYD viruses. Identifying introgressions from *Thinopyrum intermedium* in hexaploid wheat and characterizing them in terms of resistance to BYDVs. Collaborated with CSIRO (R. Appels) for evaluating the diagnostic restriction fragment 'A600' for the identification of plants with introgressions. Studies initiated at CIMMYT for using this fragment. **Publications:** 1) Bertschinger, L., M.D.H.M. William, N. Islam-Faridid, A. Cortés, D. González de León, A. Mujeeb-Kazi, A. Comeau, K.M. Makkouk, H. Ohm, and R. Appels. 1994. Progress in developing bread wheat resistant to barley yellow dwarf viruses using serological, molecular marker and molecular cytogenetic techniques. The International Conference on the Status of Research on the Plant Genome (Plant Genome II), January 24-27, 1994, San Diego, USA. 2) Bertschinger, L., E.E. Saari, D. González-de-León, M.D.H.M. William, and S. Rajaram, S. 1994. Evaluation of spring bread wheats with *Thinopyrum intermedium* derived resistance to barley yellow dwarf luteoviruses under field conditions. BYD Newsletter 5. 3) Mujeeb-Kazi, A., A. Cortés, N. Islam-Faridi, and L. Bertschinger. 1994. Cytogenetic characterization of bread wheat lines with resistance to barley yellow dwarf luteoviruses derived from *Thinopyrum intermedium*. BYD Newsletter 5. 4) Ohm, H., U. Hohmann, L. Bertschinger, M. Fischer, and R. Appels. *Agropyron* amplified sequences as probes for tracing *Agropyron*-derived BYDV resistance genes in wheat. *Genome*. In preparation. 5) A additional paper on the use of the 'A600' diagnostic restriction fragment and the characteristics of the germplasm developed is being written up.

Pathosystems research (15% of research time)

Project No. CPBD9202: Characterization of the relation between virus titres symptom, expression and yield loss in selected contrasting bread wheat and barley lines inoculated at various growth stages. Initiated studying the relation between plant age at inoculation and symptom expression, virus titres and yield loss in selected bread wheats and barleys. **Publication:** Bertschinger, L. 1993. Response of bread wheat and

barleys to four barley yellow dwarf viruses (BYDVs) inoculated at different plant ages. In page 182, Abstracts/Résumés, 6th International Congress of Plant Pathology, July 28-August 6, 1993, Montreal, Canada. Data analysis in process.

Project No. CPBD9203: Characterization of the interaction between BYDVs, host genotype and temperature in selected bread wheat lines. Initiated studying the relation between symptom expression and temperature for improving our biological understanding of the variability of symptom readings between testing sites. **Publication:** Bertschinger, L. 1993. Concentration of a barley yellow dwarf virus (BYDV) in a sensitive spring bread wheat line at different temperatures. In pages 322, Abstracts/Résumés, 6th International Congress of Plant Pathology, July 28-August 6, 1993, Montreal, Canada.

Project No. CPBD9204: Testing imidacloprid for its suitability in controlling cereal aphid populations and BYD viruses. Studying the effectiveness of a new insecticide (Imidacloprid) for controlling cereal aphids. Experiments conducted in El Batán in 1993, Yaqui 1992/93 and 1993/94, Toluca 1993/94, and El Batán 1993/94. Imidacloprid effective until booting, but requires further application if the plants are to be kept free of aphids until maturity. Data are being summarized.

Project No. CPBD9301: Initiating a studying or aberrant BYDV symptoms (leaf curling of RPV-Mex and other cereal viruses hopper transmitted), mainly through networking with other virologists (Nariño Dwarf disease in Colombia/Ecuador, resetting disease in Toluca, Mexico, MSV in Turkey). *Rhopalosiphum rufiabdominalis* Sasaki was found on bread wheat, durum wheat, triticale and barley roots and lower stems in Tepalcingo and Toluca. Colonies have been established at El Batán. Transmission studies have been carried out for understanding their role in the epidemiology of different BYDV strains in Central Mexico. **Publications:** 1) Bertschinger, L., T. Alejandre, E. Cardenas, R. Rodriguez Montessoro, R. Peña. 1994. The causal agent of the "leaf curling" symptom of wheats: identification, characterization, and host response. BYD Newsletter 5. 2) Bertschinger, L., L. Ayala, F. Paredes, G. Boccardo, R.G. Milne. 1994. Progress in deciphering the Nariño dwarf disease. BYD Newsletter 5. 3) One M. Sc. thesis project is ongoing as a subproject of CPBD9301: Tomás Alejandre, H. Identification and characterization of the causal agent of the leaf curling and leaf notching symptom of bread wheat. Master of Science thesis (M.Sc.), Colegio de Postgraduados de Montecillos, Texcoco, Mexico--The experimental part of the thesis is likely to be finished by end of mid-December 1994.

Support and aphid research--Russian wheat aphid (10% of research time)

Project CPBD8901: Collaborated with B. Skovmand (Head Germplasm Bank) in prebreeding activities identifying and analyzing sources of Russian wheat aphid resistance in Turkish wheats and dicoccums. Publications: Skovmand, B., L. Bertschinger, and J. Robinson. 1994.

Within-accession heterogeneity for reaction to the Russian Wheat Aphid (Diuraphis noxia Mordvilko) in Turkish hexaploid wheat landraces previously identified as resistant to the aphid. 2) Skovmand, B., L. Bertschinger, and J. Robinson. 1994. *Within-accession heterogeneity for reaction to the Russian Wheat Aphid (Diuraphis noxia Mordvilko) in Turkish hexaploid wheat landraces previously identified as resistant to the aphid.* *BYD Newsletter No.5.*

Other Activities and Projects

Training (10% of research time)

Special training in BYD provided at CIMMYT base (3-4 weeks) for one scientist from Ecuador (Biol. Ligia Ayala), and Pakistan (Dr. M. Bashir). They contributed to ongoing CIMMYT projects (virus monitoring CPBD8801, CIMMYT-ODA holdback project).

BYD Newsletter No. 5 (1994)

Evaluated the continuation of the BYD Newsletter (more than 300 questionnaires sent out) and options for funding the newsletter for improving communication among BYD researchers. BYD Newsletter No. 5 (1994) was printed and distributed in November 1994. Subscription procedure was initiated. Mailing list was updated: more scientists from the developing world, less from the developed world (i.e., only subscribing and paying, with a few exceptions). **Publications:** 1) Bertschinger, L. 1993.

Communication among BYDV researchers: the future of BYDV Newsletter and alternatives? BYDV evening session, 6th International Congress of Plant Pathology, July 28-August 6, 1993, Montreal, Canada. 2) Bertschinger, L. 1994. *The BYD Newsletter in the view of its readers.* BYD Newsletter 5.

National program visits

Visited Ecuadorian and Colombian national program for identifying options for future collaboration (variability studies, testing of selected germplasm with determined protocol). Participated in the Turkey virus, disease and pest survey and collected insect and leaf samples for identification of BYDVs and other cereal viruses (wheat soil-borne mosaic virus, leaf- and plant hopper-transmitted viruses) for testing at CIMMYT and in other laboratories (ICARDA, Rothamsted Experimental station, RAC Switzerland and others).

ODA holdback project CIMMYT-Rothamsted Experimental Station-ODA

Two visits of a Rothamsted Experimental Station (RES) representative hired by the project (Dr. Monique Henry) to Mexico to become familiar with germplasm improvement for BYD and the collaboration initiated with INIAP Ecuador. Planning matrix and operational plan agreement signed between CIMMYT (Wheat

Programs) and INIAP Ecuador, clarifying support and activities to be carried out. Virus survey conducted in Ecuador, laboratory and aphid greenhouse implemented and operational with project support, constant virological consultancy (via e-mail; two visits of CIMMYT project representative L. Bertschinger).

Turkey virus, disease and pest survey

Participation in the 1993 survey. Publication with O. Mamluk, K. Makkouk (ICARDA), H. Braun, in preparation. Further follow-up work specified in CPBD8801 and CPBD9301.

New BYD Screening Nurseries prepared

The 8th BYDSN for bread wheat and the 11th BYDSN for barley have been prepared and made available. They include new genotypes, the bread wheats likely with tolerance genes that are different from the *Bdv1*, and the barleys with tolerance/resistance genes that could be different from the *Yd2* gene. **Publication:** Bertschinger, L., and P.N. Fox. 1994. New barley yellow dwarf screening nurseries distributed by CIMMYT. BYD Newsletter 5.

CIMMYT Wheat Special Reports Completed or In Press
(As of December 10, 1994)

Wheat Special Report No. 1. Burnett, P.A., J. Robinson, B. Skovmand, A. Mujeeb-Kazi, and G.P. Hettel. 1991. Russian Wheat Aphid Research at CIMMYT: Current Status and Future Goals. 27 pages.

Wheat Special Report No. 2. He Zhonghu and Chen Tianyou. 1991. Wheat and Wheat Breeding in China. 14 pages.

Wheat Special Report No. 3. Meisner, C.A. 1992. Impact of Crop Management Research in Bangladesh: Implications of CIMMYT's Involvement Since 1983. 15 pages.

Wheat Special Report No. 4. Nagarajan, S. 1991. Epidemiology of Karnal Bunt of Wheat Incited by *Neovossia indica* and an Attempt to Develop a Disease Prediction System. Mexico, D.F.: CIMMYT. 69 pages.

Wheat Special Report No. 5. Rajaram, S., and M. van Ginkel. 1994 (rev.). A Guide to the CIMMYT Bread Wheat Section. 57 pages.

Wheat Special Report No. 6. Meisner, C.A., E. Acevedo, D. Flores, K. Sayre, I. Ortiz-Monasterio, and D. Byerlee. 1992. Wheat Production and Grower Practices in the Yaqui Valley, Sonora, Mexico. 75 pages.

Wheat Special Report No. 7a. Fuentes-Davila, G. and G.P. Hettel, eds. 1992. Update on Karnal Bunt Research in Mexico. 38 pages.

Informe Especial de Trigo No. 7b. Fuentes-Davila, G., y G.P. Hettel, eds. 1992. Estado actual de la investigación sobre el carbón parcial en México. 41 pages.

Wheat Special Report No. 8. Fox, P.N., and G.P. Hettel, eds. 1992. Management and Use of International Trial Data for Improving Breeding Efficiency. 100 pages.

Wheat Special Report No. 9. Rajaram, S., E.E. Saari, and G.P. Hettel, eds. 1992. Durum Wheats: Challenges and Opportunities. 190 pages.

Wheat Special Report No. 10. Rees, D., K. Sayre, E. Acevedo, T. Nava Sanchez, Z. Lu, E. Zeiger, and A. Limon. 1993. Canopy Temperatures of Wheat: Relationship with Yield and Potential as a Technique for Early Generation Selection. 32 pages.

Wheat Special Report No. 11. Mann, C.E., and B. Rerkasem, eds. 1992. Boron deficiency in Wheat. 132 pages.

Wheat Special Report No. 12. Acevedo, E. 1992. Developing the Yield Potential of Irrigated Bread Wheat: Basis for Physiological Research at CIMMYT. 18 pages.

Wheat Special Report No. 13. Morgunov, A.I. 1992. Wheat Breeding in the Former USSR. 34 pages.

Wheat Special Report No. 14. Reynolds, M., E. Acevedo, O.A.A. Ageeb, S. Ahmed, L.J.C.B. Carvalho, M. Balata, R.A. Fischer, E. Ghanem, R.R. Hanchinal, C.E. Mann, L. Okuyama, L.B. Olegbemi, G. Ortiz-Ferrara, M.A. Razzaque, and J.P. Tandon. 1992. Results of the 1st International Heat Stress Genotype Experiment. 19 pages.

- Wheat Special Report No. 15.** Bertschinger, L. 1994. Research on BYD Viruses: A Brief State of the Art of CIMMYT's Program on BYD and Its Future Research Guidelines. 39 pages.
- Wheat Special Report No. 16.** Acevedo, E., and G.P. Hettel, eds. A Guide to the CIMMYT Wheat Crop Management & Physiology Subprogram. 161 pages.
- Wheat Special Report No. 17.** Huerta, J., and A.P. Roelfs. 1994. The Virulence Analysis of Wheat Leaf and Stem Rust on a Worldwide Basis. In press--scheduled for release in late 1994.
- Wheat Special Report No. 18.** Bell, M.A., and R.A. Fischer. 1993. Guide to Soil Measurements for Agronomic and Physiological Research in Small Grain Cereals. 40 pages.
- Wheat Special Report No. 19.** Woolston, J.E. 1993. Wheat, Barley, and Triticale Cultivars: A List of Publications in Which National Cereal Breeders Have Noted the Cooperation or Germplasm They Received from CIMMYT. 68 pages
- Wheat Special Report No. 20.** Balota, M., I. Amani, M.P. Reynolds, and E. Acevedo. 1993. An Evaluation of Membrane Thermostability and Canopy Temperature Depression as Screening Traits for Heat Tolerance in Wheat. 26 pages.
- Informe Especial de Trigo No. 21a.** Moreno, J.I., y L. Gilchrist S. 1994. La roña o tizón la espiga del trigo. 25 pages.
- Wheat Special Report No. 21b.** Moreno, J.I., and L. Gilchrist S. 1994. Fusarium head blight of wheat. 25 pages.
- Wheat Special Report No. 22.** Stefany, P. 1993. Vernalization Requirement and Response to Day Length in Guiding Development in Wheat. 39 pages.
- Wheat Special Report No. 23a (short version).** Dhillon, S.S., and I. Ortiz-Monasterio R. 1993. Effects of Date of Sowing on the Yield and Yield Components of Spring Wheat and Their Relationships with Solar Radiation and Temperature at Ludhiana (Punjab), India. 33 pages.
- Wheat Special Report No. 23b (long version).** Dhillon, S.S., and I. Ortiz-Monasterio R. 1993. Effects of Date of Sowing on the Yield and Yield Components of Spring Wheat and Their Relationships with Solar Radiation and Temperature at Ludhiana (Punjab), India. 83 pages.
- Wheat Special Report No. 24.** Saari, E.E., and G.P. Hettel, eds. 1994. Guide to the CIMMYT Wheat Crop Protection Subprogram. 132 pages.
- Wheat Special Report No. 25.** Reynolds, M.P., E. Acevedo, K.D. Sayre, and R.A. Fischer. 1993. Adaptation of Wheat to the Canopy Environment: Physiological Evidence that Selection for Vigor or Random Selection May Reduce the Frequency of High Yielding Genotypes. 17 pages.
- Wheat Special Report No. 26.** Reynolds, M.P., K.D. Sayre, and H.E. Vivar. 1993. Intercropping Cereals with N-Fixing Legume Species: A Method for Conserving Soil Resources in Low-Input Systems. 14 pages.

Wheat Special Report No. 27. Yang Zhuping. 1994. Breeding for Resistance to Fusarium Head Blight of Wheat in the Mid- to Lower Yangtze River Valley of China. 16 pages.

Wheat Special Report No. 28. Rees, D., L. Ruis Ibarra, E. Acevedo, A. Mujeeb-Kazi, and R.L. Villareal. 1994. Photosynthetic Characteristics of Synthetic Bread Wheats. 40 pages.

Wheat Special Report No. 29. Rajaram, S., and G.P. Hettel, eds. 1994. Wheat Breeding at CIMMYT: Commemorative 50th Anniversary Issue. In press--scheduled for release in early 1995.

Wheat Special Report No. 30. Delgado, M.I., M.P. Reynolds, A. Larqué-Saavedra, and T. Nava S. 1994. Genetic Diversity for Photosynthesis in Wheat under Heat-Stressed Field Environments and Its Relation to Productivity. 17 pages.

Wheat Special Report No. 31. Reynolds, M.P., O.A.A. Ageeb, J. Cesar-Albrecht, G. Costa-Rodrigues, E.H. Ghanem, R.R. Hanchinal, C. Mann, L. Okuyama, L.B. Olugbemi, G. Ortiz-Ferrara, S. Rajaram, M.A. Razzaque, J.P. Tandon, and R.A. Fischer. 1994. The International Heat Stress Genotype Experiment: Results from 1990-1992. In press.

Wheat Special Report No. 32. Bell, M.A., and R.A. Fischer. 1994. Guide to Plant and Crop Sampling: Measurements and Observations for Agronomic and Physiological Research in Small Grain Cereals. 66 pages,

Wheat Special Report No. 33. Bell, M., R. Raab, and A. Violic. 1994. Setting Research Priorities for Agronomic Research: A Case Study for Wheat in Chalco, Mexico. 20 pages.

Wheat Special Report No. 34. Bell, M.A. 1994. Four Years of On-Farm Research Results at Chalco, Mexico. 35 pages.

Wheat Special Report No. 35. Bell, M.A., H.A. Muhtar, J.A. Stewart, and F. Gonzalez. 1994. Assessment and Development of an Agricultural Research Station: Physical and Personnel Needs. 16 pages.

Wheat Special Report No. 36. Dubin, H.J., and H.P. Bimb. 1994. Studies of Soilborne Diseases and Foliar Blights of Wheat at the National Wheat Research Experiment Station, Bhairahawa, Nepal. 30 pages.

Wheat Special Report No. 37. Skovmand, B. 1995. Wheat Cultivar Abbreviations. Paper and diskette versions. In press--scheduled for distribution in March 1995 as part of GRIP (Genetic Resource Information Package). Note: Listed as Special Report No. 4 in some previous lists.



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