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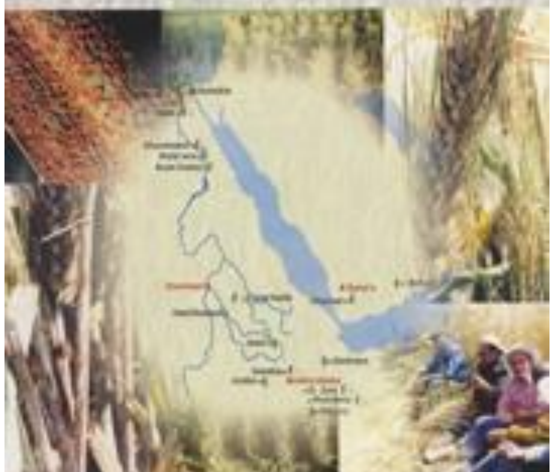
Incidence, Spore Movement, Pathotypes and Effective Resistance Genes



Nile Valley and Red Sea Regional Program
International Center for Agricultural Research in the Dry Areas

WHEAT LEAF AND STEM RUSTS IN THE NILE VALLEY AND RED SEA REGION

Incidence, Spore Movement, Pathotypes and Effective Resistance Genes

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Nile Valley and Red Sea Regional Program (NVRSRP)
International Center for Agricultural Research in the Dry Areas (ICARDA)

Supported by
The Directorate of International Cooperation (DGIS) of the Netherlands Government

December 2000

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Citation:
Mamluk, O.F., Y.H. El-Daoudi, E. Bekele, M.B. Solh, M.S. Ahmed, M.A. Mahir and H.S. Bahamish. 2000. Wheat Leaf and Stem Rusts in the Nile Valley and Red Sea Region. ICARDA/NVRSRP, Cairo, Egypt. vi + 75 p.

ISBN: 977-302-040-1

Language editor: Hala Hafez

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FOREWORD

Wheat is an important staple food crop and an essential component in the daily diets of the people of the Nile Valley and Red Sea countries: Egypt, Ethiopia, Sudan, and Yemen. With self-sufficiency ranging between 11% (Yemen) and 55% (Egypt), all four countries import substantial quantities of wheat annually to meet the demand of their fast-growing populations. Leaf and stem rusts are the major diseases that cause heavy losses in wheat production and threaten the stability of high-yielding varieties in the region. Therefore, it is essential to control these diseases to increase wheat productivity and stabilize wheat production.

The effect of wheat rusts on productivity depends largely on the prevailing pathogen pathotypes or races and their compatibility with the host crop in a given environment. The rapidly evolving wheat rust races require close monitoring and continuous assessment of sources of resistance, and identifying genes for durable resistance in each country and across the region.

A regional approach of research on wheat rusts is extremely important, since rust spores are airborne and are carried by wind over long distances, thus contributing to a rapid spread of the diseases across countries and from one region to another. In addition, complementary research at the regional level makes better use of the limited human and physical resources available in the region.

Guided by this approach, research on wheat rusts started in the 1988/89 growing season within the Nile Valley and Red Sea Regional Program (NVRSRP), with available resources from the countries involved. It was further strengthened when the Netherlands Government approved a 3-year (1995–1997) regional project, of which rust disease control was a major component. The project involves six partners: Egypt, Ethiopia, Sudan, Yemen, ICARDA and CIMMYT. Wheat rust network activities still continue beyond the completion of the project, with resources from the national programs. Egypt plays the leading technical role in the regional network, while ICARDA provides technical backstopping and contributes to the network management. Research is jointly planned, but conducted and reported by national scientists. Activities within each participating country are undertaken by its national agricultural research system: the Agricultural Research Center (ARC) in Egypt, the Ethiopian Agricultural Research Organization (EARO) in Ethiopia, the Agricultural Research Corporation (ARC) in Sudan, and the Agricultural Research and Extension Authority (AREA) in Yemen.

The intensive work that has been carried out within the few years of the project's life has produced useful results, which are contributing to the development of durable resistance to leaf and stem rusts in wheat. This publication provides an overview of the achievements made. It is hoped that these ongoing efforts will help in increasing wheat production in the partner countries, and contribute to self-sufficiency and alleviating hunger.

Prof. Dr. Adel El-Beltagy
Director General
ICARDA

ACKNOWLEDGEMENTS

This study was conducted within the Wheat Rusts Network of the Regional Networks Project, which was supported by the Directorate of International Cooperation (DGIS) of the Netherlands Government. The project, which is part of the Nile Valley and Red Sea Regional Program (NVRSRP), involves countries of the Nile Valley and Red Sea region: Egypt, Ethiopia, Sudan and Yemen.

The authors appreciate the technical support of many scientists in the four countries, as indicated below:

In Egypt: Ikhlas Shafik, S. Sherif, I.A. Imbaby, R.A. Abou El-Enein, A.A. Abdel-Shafi, Enayat H. Ghanem, R.A. Mitkees and S.A. Bekheet (Giza, ARC)

S. Abul-Naga, M.O. Khalifa, A.A. Bassiouni and Y.A. Youssef (Sakha Agricultural Research Station, ARC)

M. El-Shamy (Gemmeiza Agricultural Research Station, ARC)

In Sudan: S. Ali and M.T. Malkha (New Halfa Agricultural Research Station, ARC)

In Ethiopia: Rebeka Desten (Holetta Research Center, Holetta, IAR)

Ayele Badebo (Kulumsa Research Center, Kulumsa, IAR)

Yeshi Andnew (Alemaya University of Agriculture, Debre Zeit)

Masresha Aklilu (Plant Protection Research Center, Ambo)

Melkamu Ayalew (Adet Research Center, Adet, IAR)

Mengistu Hulluka (Alemaya University of Agriculture, Alemaya)

Bekele Hunde (Sinana Research Center, Sinana, IAR)

In Yemen: A. Al-Ansi (Dhamar, AREA)

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EXECUTIVE SUMMARY

Wheat production is important in the Nile Valley and Red Sea countries. The average yearly wheat area harvested during 1993–1995 was 952,000, 884,000, 325,000 and 103,000 ha in Egypt, Ethiopia, Sudan and Yemen, respectively. The respective average yearly wheat production for the same period was 4.99, 1.27, 0.48 and 0.16 million tonne. All four countries import wheat annually to satisfy the demand of their rapidly increasing populations.

Wheat rust diseases (stripe, leaf and stem rusts) are still the major biotic stresses on wheat in the Nile Valley and Red Sea region and are considered the main factors for limiting wheat production and longevity of the high-yielding varieties. The impact of the effect of rust diseases depends largely on the prevailing pathogen pathotypes and their compatibility with the genetic constitution of the host crop in a given environment.

The main objectives of the present work were to (1) determine the sources of the primary inoculum, pathways of the inoculum in the region and the first occurrence of rust incidence, (2) identify sources of long-lasting resistance, and (3) monitor the present status of stable leaf and stem rust pathotypes in the four countries. This was accomplished with the assistance of the Nile Valley and Red Sea Wheat Rust Trap Nursery (NVRSWRTN), which was located at 22 sites in the region during five growing seasons (1992/93–1996/97): 12 in Egypt, 1 in Sudan, 7 in Ethiopia and 2 in Yemen. The nursery included 60 entries: 7 leaf rust isogenic lines, 10 stem rust isogenic lines, 2 leaf and stem rust isogenic lines, 33 high-yielding cultivars (Egypt 16, Ethiopia 9, Sudan 5 and Yemen 3), 2 susceptible checks (*Triticum spelta saharense* and Little Club), and 6 wheat wild relatives (2 *Triticum boeoticum* and 4 *T. dicoccoides*), known for their susceptibility to leaf and stem rusts. Also, Burkard spore trap samplers were installed at 7 locations in the region: 3 in Egypt (Nubaria, Sids and Shandaweel), 3 in Ethiopia (Debre Zeit, Holetta and Kulumsa) and 1 in Sudan (New Halfa). The samplers were operating all year round from January 1993 to August 1997.

From the results it was concluded that in Egypt, March could be considered the month for the first occurrence and development of leaf rust, while stem rust starts in the middle of April. In Ethiopia, the first occurrence of both rusts is in August, while in Sudan, the first stem and leaf rust occurrence is usually observed by the last week of December. In Egypt, the primary inoculum seems to be coming from the northern countries due to the main wind direction in Egypt during the wheat-growing season. In Ethiopia and Yemen, the primary inoculum is endogenic due to the presence of wheat plants during the whole year. In Sudan, there is no chance for urediospores to over-summer, and the primary inoculum comes from outside, maybe from Ethiopia, Yemen or other neighboring African countries.

Twenty-eight leaf rust pathotypes were identified during the five growing seasons in Egypt (19), Ethiopia (16), Sudan (5) and Yemen (6). Pathotype 12 was common in all countries followed by pathotypes 57, 77, 144 and 151. Nineteen stem rust pathotypes were also identified during the same period in Egypt (16), Ethiopia (16), Sudan (10) and Yemen (9). Five pathotypes (14, 15, 17, 19 and 24) were found common in all countries. Also common, but to a lesser extent, were pathotypes 39, 53, 122 and 123.

The most effective leaf-rust-resistant gene in the region was *Lr 17* at both the seedling and adult stages, while *Lr's 2, 2a, 3ka, 11, 21* and *30* were effective at the seedling stage. Stem rust gene *Gt*– was the most effective in the region at both stages, while *Sr's 7b, 8a* and *30* were effective only at the seedling stage.

Cultivated wheat genotypes showed good levels of resistance, and the lowest average coefficient of infection (ACI) for leaf rust was found on varieties Giza 157, Giza 162, Giza 165, Sakha 8 and Sakha 69 (Egypt); Dashen, ET-13, K 6295-4A and C.T. 71/CII (Ethiopia); Debeira, Condor and Condor 'S' (Sudan); and Marib 1 (Yemen). For stem rust, the lowest ACI was on cultivars Giza 155, Giza 164, Sakha 69, Sakha 92 and Gemmeiza 1 (Egypt); K 6890-B, Dashen, ET-13, K 6295-4A, C.T. 71/CII, Bohai and Cocorit 71 (Ethiopia); Condor 'S' (Sudan); and Aziz and Marib 1 (Yemen). Seven cultivars (Sakha 69, Dashen, ET-13, K 6295-4A, Condor 'S', C.T. 71/CII and Marib 1) performed well against both rusts.

In Egypt, the largest number of trapped spores of both leaf and stem rust was in March in Nubaria and Sids (northern and central Egypt), while the peak count was in April in Shandaweel (southern Egypt). The number of trapped spores increased with crop development, from flowering till the mature stage or during February–May.

In Ethiopia, the peak spore count for both rusts was in October at Holetta and Kulumsa, and in November at Debre Zeit, mainly due to late planting of durum wheat. In Sudan, the spore count started to increase in November at the time of cultivation of the crop and continued until April after peaking in March. The continuous spore catch during the non-cropping months in Egypt and Sudan suggested that the spores trapped during that period were mainly from external sources.

Generally, the peak spore loads of both rusts were in March in Egypt, in November in Ethiopia, and in February in Sudan. Except for the two-month gap between November and February, this sequence could suggest that the spores follow a northward movement and initiate infection following the cropping pattern.

INTRODUCTION

WHEAT CROPPING

Egypt, Ethiopia, Sudan and Yemen are the countries involved in the Wheat Rusts Network within the Problem-Solving Regional Networks Project of the Nile Valley and Red Sea Regional Program (NVRSRP). Wheat production is important in these countries. Aspects related to this production are also important, in particular the wheat cropping pattern and the biotic stresses. The average annual wheat area harvested during 1993–1995 was 952,000, 884,000, 325,000 and 103,000 ha in Egypt, Ethiopia, Sudan and Yemen, respectively. The respective average annual wheat production for the same period was 4.99, 1.27, 0.48 and 0.16 million tonne, while the average yield was 5.3, 1.4, 1.5 and 1.6 t/ha (Aquino *et al.* 1996). The four countries are wheat importers; the respective average net imports per year during 1992–1994 were 5.95, 0.39, 0.46 and 1.65 million tonne (Aquino *et al.* 1996). These countries have an immediate need to increase their wheat production to sustain the fast population growth (Table 1).

Table 1. Population and average wheat data in the Nile Valley countries and Yemen.

Item	Egypt	Ethiopia	Sudan	Yemen
Estimated population (million), 1995	62.9	58.6	28.1	14.5
Average harvested wheat area (1000 ha), 1993–1995	952.0	884.0	325.0	103.0
Average wheat production (million tonne), 1993–1995	4.99	12.7	0.483	0.167
Average wheat yield (t/ha), 1993–1995	5.3	1.4	1.5	1.6
Average net imports of wheat (1000 t), 1992–1994	5949.0	391.0	460.0	1653.0

Source: Aquino *et al.* (1996).

Wheat is grown in Egypt under irrigation, with only one cropping season between November and June. Bread wheat (*Triticum aestivum* L.) is the major and most commonly grown wheat. Durum wheat (*Triticum turgidum* L var. *durum*) dominates in the southern part of the country and covers about 2% of the total wheat area.

In Ethiopia, wheat is grown at altitudes ranging from 1500 to 3000 m asl, with the most suitable areas falling between 1900 and 2700 m asl (Gebre-Mariam 1991). The rainy season is divided into a short rain season (*Belg*) from February to April and the main rain season (*Meher*) form June to September. In the highlands, the rainfall distribution is bimodal and ranges between 600 and 2000 mm per annum. Wheat is produced largely in the main season (*Meher*). Its production in the short season (*Belg*) is only 3.5% of the total cultivation (CSA 1996a). About 60% of the wheat area is occupied by durum wheat and 40% by bread wheat.

In Sudan, wheat is grown mainly in New Halfa, but also in the Gezira, Rahad and the Northern State under irrigation between November and March. In Yemen, wheat is grown in the highlands in two cycles, mainly in the winter season, from November to May, and the off-season or summer season, from July to November. In the mid-elevation areas, it is grown only in one season, from October to March, with supplemental irrigation. Some farmers achieve three crops per year under continuous cultivation with supplemental irrigation. No durum wheat is grown in Sudan or Yemen.

CULTIVARS GROWN

The Wheat Research Program in Egypt started in 1920 with initial activities based on mass selection to improve introduced Indian germplasm and local material. However, the selected genotypes were not grown on a large scale due to their low productivity, rust susceptibility and poor agronomic and technical qualities. In the 1940s, hybridization was started between local and introduced germplasm, and the Egyptian wheat cultivar Giza 139 was a result of these efforts. In the 1950s and 60s, other commercial wheat cultivars (Giza 144, Giza 150, Giza 155 and Giza 156) were released. These cultivars increased the national average yield per unit area from 1.7 to 3.0 t/ha. In the early 1980s, six commercial cultivars were released (Giza 157, Giza 158, Giza 160, Sakha 8, Sakha 61 and Sakha 69), followed by 10 varieties in the late 1980s and early 1990s. However, the main bread wheat cultivars grown since the 1990s are Giza 165, Giza 167, Gemmeiza 1, Gemmeiza 3, Sids 1, Sids 6, Sids 7, Sids 8, Sids 9 and Sahel 1. The main durum wheat cultivars are Sohag 1, Sohag 2, Sohag 3, Beni Suef 1 and Beni Suef 3 (El-Sayed *et al.* 1996; Ghanem *et al.* 1991, 1994, 1996a, 1996b, 1996c).

The majority of farmers in Ethiopia still use landrace varieties, and only about 20.8% of the wheat area is occupied by improved cultivars (CSA 1996a). Although a large number of cultivars of both bread and durum wheat have been released in Ethiopia since 1967, many of these were put out of production due to their susceptibility to diseases, mainly wheat rusts. The relatively stable and resistant cultivar Enkoy, that has been in production for more than two decades, has been dropped out of production in the early 1990s due to its susceptibility to a virulent stem rust race(s). However, this cultivar is still widely grown by farmers. Currently, not more than a dozen cultivars of both bread and durum wheat are under production. The popular cultivar ET-13, which has been widely grown by farmers for a long time, still possesses a good level of resistance to all three rusts. Four more new bread wheat cultivars, Kubsa (HAR 1685), Galama (HAR 604), Mitike (HAR 1709) and Wabe (HAR 710), released in 1994/95, showed good levels of resistance to the prevailing rust races and are expected to be widely used by farmers. A number of durum cultivars have been released and are widely grown by farmers in vertisol areas (CSA 1996b, c).

In Sudan, the main cultivars grown since 1965 are H 57, H 164, Mexican, Condor 'S', Wadi El-Neil, Debeira, Sasaraib and El-Neilain.

In Yemen, more than 18 old "classical" landraces are still grown by farmers. These are typically tetraploid types, especially *T. dicoccum* or emmer wheat. Cultivars Ahgaff (= Nortino), Anza, Aziz (= Seri 82), Bahouth, Marib (= Pavon), Mokhtar (= V), Siwairi and Sonalika are the main semi-dwarf spring wheat cultivars grown at present.

RUST DISEASES AND THEIR IMPACT ON WHEAT PRODUCTION

Wheat in the Nile Valley and Red Sea region is subjected to a number of biotic agents, such as rusts, loose smut, powdery mildew, barley yellow dwarf virus, and aphid insects. Wheat rust diseases, particularly leaf rust (*Puccinia recondita* Rob. ex Desm. f.sp. *tritici*) and stem rust (*P. graminis* Pers. f.sp *tritici* Erikss & Henn.), occur in epiphytotic forms and are still the main factors that limit wheat production and longevity of the adapted high-yielding cultivars. Yellow (stripe) rust (*Puccinia striiformis* West. f.sp. *tritici*) occurs in waves of 10–20 years in Egypt, with the last severe epiphytotic in 1995 (El-Daoudi *et al.* 1996b; Abul-Naga *et al.* 1997). The disease is endemic in Ethiopia and Yemen and occurs in several forms. Yellow rust has never been reported in Sudan. In a given environment, the impact of rust incidence and development depends largely on the prevailing pathogen pathotypes and their compatibility with the genetic constitution of the host.

During the 1940s, the wheat cultivar Giza 139 was released in Egypt. It was resistant to stem rust but was hit afterwards by leaf rust. The failure of the Mexican wheat cultivars Mexipak 69, Super X and Chenab 70 to resist leaf rust infection in 1978 resulted in losses estimated at 10.9, 12.9 and 23.2%, respectively (El-Daoudi 1983).

Yield reduction caused by stem rust disease in the Egyptian cultivars Giza 155, Giza 157, Sakha 8, Sakha 61, Sakha 69, Giza 160 and Giza 162 varied among the cultivars. Sakha 69 showed the best performance with less than 3% reduction in kernel weight at up to 50% stem rust infection. Also, the coefficient of determination (r^2) was lowest for Sakha 69 (0.15) and Giza 162 (0.56). For all the other tested cultivars, it was higher than 0.90 (El-Daoudi *et al.* 1990).

Leaf and stem rust diseases s were recorded in Ethiopia as early as the 1930s (Castellani 1938; Sibilia 1938). As a group, they have been the most important diseases of wheat in Ethiopia, with stem rust being the most destructive at altitudes below 2300 m asl. Leaf rust occurs endemically in most regions, while stripe rust is important at higher altitudes. A field experiment conducted at Holetta in the late 1960s showed that yield losses of 96, 75 and 61% were recorded in early-sown wheat crop due to stripe, leaf and stem rusts, respectively (Bekele 1985).

In Sudan, leaf and stem rusts are very important diseases of wheat. Both rusts are confined to the New Halfa area and are rarely seen in other wheat-growing areas. Stem rust is considered more severe and more destructive than leaf rust due to the weather conditions that are more conducive to the development of stem rust. Progress of stem rust infection continues during the whole season, while that of leaf rust is usually interrupted.

In Yemen, the three rusts occur annually; however, in recent years, yellow rust is considered the most common rust disease and devastates the entire wheat crop.

RESEARCH CONDUCTED ON WHEAT RUST DISEASES

The pathogens causing stem and leaf rust diseases multiply and are dispersed by means of their urediospores. These spores are airborne and can be dispersed over long distances. In spite of much effort devoted to control the diseases by selecting resistant cultivars, stability and durability could not be sustained. This is partly due to minimal attention paid to study the epidemiology of the diseases and due to the uncoordinated approach to monitoring rust race development. Knowledge of the rust epidemiology is needed to devise breeding policies for resistance. This knowledge would clarify whether rusts are endemic to a particular country that constitutes one epidemiological unit or whether there is an influx of inoculum from outside the country, and would help in designing the strategy for the management of these rusts in the region as a whole.

Epidemiological studies in Egypt have given indications of the movement pattern of the rust spores in the country and have determined the geographical distribution of the physiological races (Abdel-Hak *et al.* 1966a; Abdel-Hak and Kamel 1971). Also, different physiological races of both pathogens have been identified in Egypt and in other countries of the region (Abdel-Hak *et al.* 1966b; Abul-Naga *et al.* 1990). Identification of pathogen pathotypes or races, virulence changes and race dynamics in Egypt and neighboring countries is routinely carried out at the Cereal Disease Research Department of the Agricultural Research Center in Giza, Egypt.

In Ethiopia, studies conducted in the past on race composition and the pattern of virulence of stem and leaf rusts have been reviewed (Hulluka *et al.* 1991). Highly heterogeneous and virulent races of both rusts were reported to occur in the country. More recently, the Ethiopian Rust Trap Nursery (ERTN) was assembled to provide insight into the virulence spectra (Getinet *et al.* 1990). However, studies to determine primary sources of inoculum of these rusts and their pathways are scarce. A review by Hulluka *et al.* (1991) revealed a wide spectrum range of physiologic races and virulence of both rusts, identified since the 1950s. The ERTN, planted at hot-spot locations representing the major wheat growing regions of Ethiopia, has been used as an important tool for monitoring the rust race and virulence situation each season (Getinet *et al.* 1990; Hulluka *et al.* 1991). Valuable information on the distribution and frequency of the races and the occurrence of new races or virulence has been obtained from this activity. Stubbs (1988) showed similarities among the stripe rust race patterns in East Africa, particularly between Ethiopia and Kenya. A similar situation could be expected to occur for leaf and stem rusts.

In Sudan, scattered research work on race analysis of leaf and stem rusts has been done outside the country. Important questions on the epidemiology and pathotypes of the two rusts remain unanswered.

In Yemen, work on race analysis has been carried out outside the country. Information on leaf and stem rusts and their epidemiology is not available.

OBJECTIVES

The overall objectives of this study were as follows:

- Determine dates of the first spore and disease incidence of rusts in relation to weather data.
- Monitor the present status of leaf and stem rust pathotypes and their frequencies in each country and in the region during 1992–1997.
- Identify the effective genes conditioning resistance in the countries/region against the prevalent rust pathotypes.
- Test the performance of commercially grown cultivars and advanced lines against the rust populations in the region.
- Generate systematic information on leaf and stem rusts in the region to facilitate effective breeding programs.

METHODOLOGY

The methods in this study for monitoring the present status of leaf and stem rust pathotypes and spore movement involved the use of the Nile Valley and Red Sea Wheat Rust Trap Nursery (NVRSWRTN) and mechanical spore trapping through Burkard spore traps. Virulence analysis was conducted after sampling and identifying the present pathotypes. Sources of resistance genes were abstracted from the reactions of isogenic lines in the NVRSWRTN and pathogenicity tests. The nursery was also used as a vehicle to test the performance of commercial cultivars and promising lines, developed by each of the breeding programs of the collaborating countries, against the rust populations prevailing in the region.

NILE VALLEY AND RED SEA WHEAT RUST TRAP NURSERY (NVRSWRTN)

The NVRSWRTN was planted and evaluated for five seasons, 1992/93–1996/97. Initially, the nursery was composed of 50 lines including rust differentials and commercially grown cultivars. Later, it included 60 lines: 7 leaf rust isogenic lines, 10 stem rust isogenic lines, 2 leaf and stem rust isogenic lines, 33 commercial cultivars (Egypt 16, Ethiopia 9, Sudan 5 and Yemen 3), 2 susceptible checks (*Triticum spelta saharense* and Little Club), and 6 wheat wild relatives (2 *Triticum boeoticum* and 4 *T. dicoccoides*), known for their susceptibility to leaf and stem rusts. With these lines and cultivars, it was aimed to select all possible and specific virulences from the rust populations (Table 2). The nursery was planted during the years of the study in areas where rust diseases occur naturally, and during the main season in Ethiopia and Yemen. In Egypt and Sudan, the planting date was the second half of November; in Ethiopia, the first week of July; and in Yemen, in October–November. Each line was planted in two rows, 2 m long and 30 cm apart.

In general, there were 22 sites in which the nursery was planted (12 in Egypt, 7 in Ethiopia, 1 in Sudan and 2 in Yemen). These sites represent the main wheat-growing areas of the region (Fig. 1). Disease notes were recorded in field books distributed with the seed to the collaborators in the study, and included the first disease incidence observed on any of the nursery's entries or on any cultivar in commercial fields in the vicinity of the nursery. The score for disease severity, expressed as the percentage coverage of leaves with rust pustules (Peterson *et al.* 1948), and plant reaction, expressed in five infection types (Stakman *et al.* 1962), were recorded for each entry in the nursery as follows: 0 = immune, R = resistant, MR = moderately resistant, MS = moderately susceptible, and S = susceptible.

The average coefficient of infection (ACI) was calculated using an adapted scale of Saari and Wilcoxson (1974) as follows: 0 = no infection, R = 0.2 (resistant), MR = 0.4 (moderately resistant), X = 0.61 (mixed reaction), MS = 0.8 (moderately susceptible), and S = 1.0 (susceptible).

Table 2. The Nile Valley and Red Sea Wheat Rust Trap Nursery (NVRSWRTN).

No	Line/Cultivar		Origin	CI/PI or RL	*Lr* or *Sr* gene
1	Thatcher^6 × Webster		USA	RL 6016	*Lr 2a*
2	Thatcher^6 × Hussar		USA	RL 6053	*Lr 11*
3	Thatcher^6 × Transfer		USA	RL 6010	*Lr 9*
4	Thatcher^6 × Klein Lucero		USA	RL 6008	*Lr 17*
5	Thatcher^6 × Africa 43		USA	RL 6009	*Lr 18*
6	Thatcher^6 × RL 5406		USA	RL 6043	*Lr 21*
7	Thatcher^6 × Lee 310		USA	RL 6012	*Lr 23*
8	Thatcher^6 × Agent		USA	RL 6064	*Lr 24* & *Sr 24*
9	Imperial rye		USA	RL 6078	*Lr 26* & *Sr 31* & *Yr 9*
10	Prelude × Reliance		USA	*ISr 5*-Ra	*Sr 5*
11	Red Egyptian		USA	*ISr 6*-Ra	*Sr 6*
12	Vernstein		USA	Vernstein	*Sr 9e*
13	Line AG		USA	*ISr 11*-Ra	*Sr 11*
14	Einkorn		USA	*T. monococcum*	*Sr 21*
15	LC *Sr 25* Ars		USA	LC *Sr 25* Ars	*Sr 25*
16	Eagle		USA	Eagle	*Sr 2* & *Sr 26*
17	W2691 *Sr 27*		USA	W2691	*Sr 27*
18	Gamut		USA	CI 32930	*Sr Gt*$^+$
19	*Triticum timopheevii*		USA	PI 210970	*Sr Tt-1 (36)*
20	Giza 155	(BW)	Egypt		
21	Giza 157	(BW)	Egypt		
22	Giza 160	(BW)	Egypt		
23	Giza 162	(BW)	Egypt		
24	Giza 163	(BW)	Egypt		
25	Giza 164	(BW)	Egypt		
26	Giza 165	(BW)	Egypt		
27	Sakha 8	(BW)	Egypt		
28	Sakha 69	(BW)	Egypt		
29	Sakha 92	(BW)	Egypt		
30	Gemmeiza 1	(BW)	Egypt		
31	Gemmeiza 3	(BW)	Egypt		
32	Beni Suef	(BW)	Egypt		
33	Sohag 1	(BW)	Egypt		
34	Sohag 2	(BW)	Egypt		
35	Sohag 3	(BW)	Egypt		
36	Debeira	(BW)	Sudan		
37	Condor	(BW)	Sudan		
38	Condor 'S'	(BW)	Sudan		
39	El-Neilain	(BW)	Sudan		
40	Baladi	(BW)	Sudan		
41	Enkoy	(BW)	Ethiopia		
42	K 6890-Bulk	(BW)	Ethiopia		
43	Dashen	(BW)	Ethiopia		
44	ET-13	(BW)	Ethiopia		
45	K 6295-4A	(BW)	Ethiopia		
46	C.T. 71/CII	(BW)	Ethiopia		
47	Bohai	(BW)	Ethiopia		
48	Cocorit	(BW)	Ethiopia		
49	DZ 04-118	(DW)	Ethiopia		
50	Mokhtar	(BW)	Ethiopia		
51	Aziz	(BW)	Yemen		
52	Marib 1	(BW)	Yemen		
53	*Triticum spelta saharense*		Check		
54	Little Club		Check		
55	*Triticum boeoticum*		ICARDA	No. 600674	
56	*T. boeoticum*		ICARDA	No. 600672	
57	*T. dicoccoides*		ICARDA	No. 600673	
58	*T. dicoccoides*		ICARDA	No. 600675	
59	*T. dicoccoides*		ICARDA	No. 600679	
60	*T. dicoccoides*		ICARDA	No. 6006715	

CI = Cereal Investigation Accession Number, U.S. Department of Agriculture; PI = Plant Introduction Number, U.S. Department of Agriculture; RL = Rust Laboratory Number, Canada Department of Agriculture; BW = Bread wheat; DW = Durum wheat.

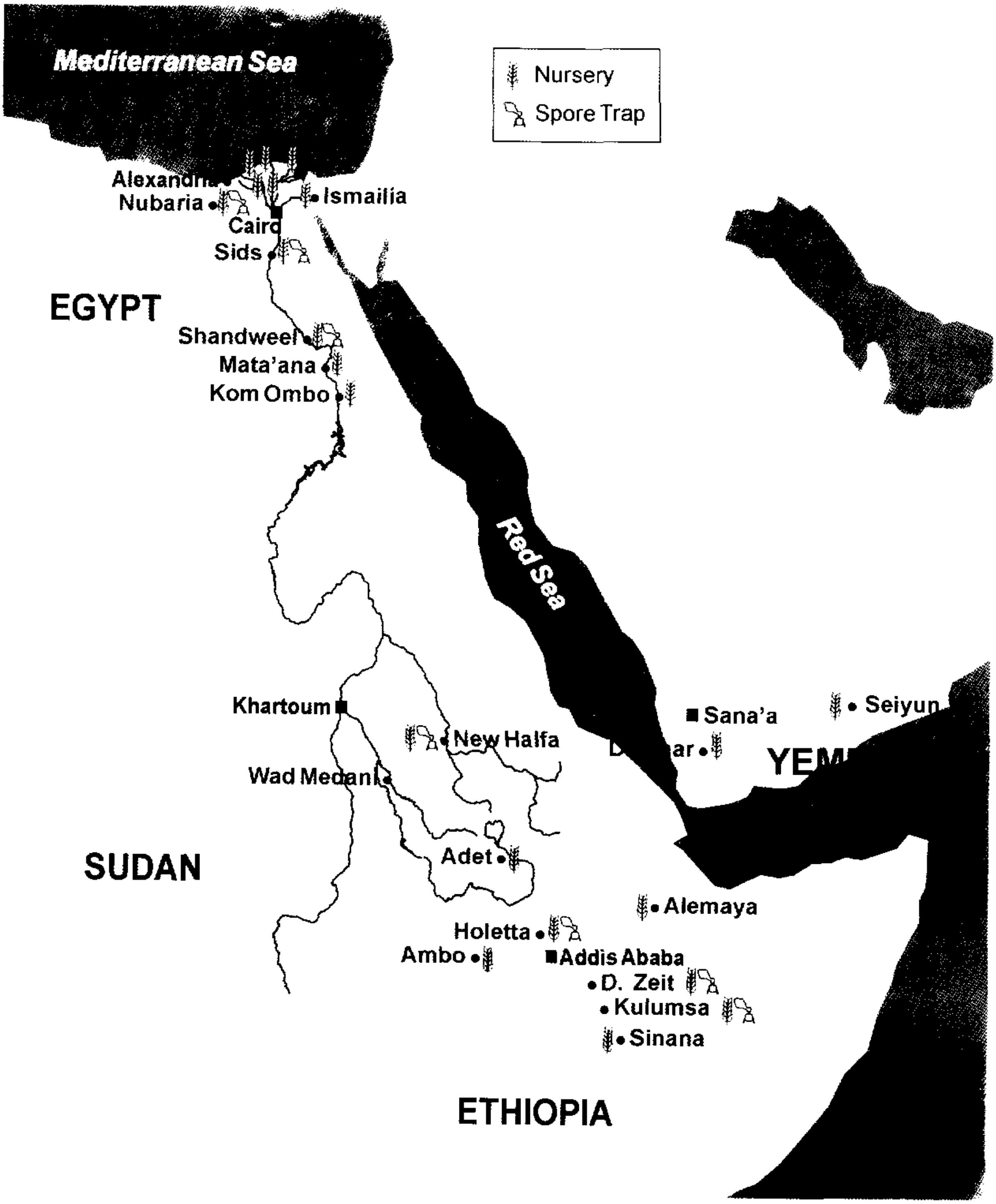


Fig. 1. Planting sites of the Nile Valley and Red Sea Wheat Rust Trap Nursery, and locations of the spore traps in Egypt, Ethiopia, Sudan and Yemen.

Identification of Pathotypes and Sources of Resistance

For pathotype identification and virulence analysis, diseased leaf and stem rust samples were collected at each planting site of the NVRSWRTN from fresh and heavily infected lines as well as from lightly infected lines. Samples were also collected form commercial cultivars grown in the main wheat cultivation areas of each country. Glassine envelopes were used for collecting the samples.

The collected rust specimens were labeled adequately and exposed to room conditions for 24 hours to reduce humidity in the samples. The samples were stored in a desiccator inside the refrigerator at 2 to 5°C. Samples collected from all sites and countries in the region were sent by express mail or were hand-carried to the Cereal Disease Research Department in Giza, Egypt. The samples were processed immediately after arrival or stored in a refrigerator until processing.

Rust Spore Multiplication

The collected disease specimens were moistened and the spores transferred onto susceptible seedlings for multiplication. Seedling plants of two susceptible cultivar, Giza 139 to leaf rust and Little Club to stem rust, were grown in 10 cm plastic pots containing sterilized soil. Seven- to eight-day-old seedlings, with the first leaf unfolded, were used for spore multiplication. The first leaf was gently rubbed between moistened fingers, wetted with tap water and atomized to produce initial dew on the leaf surface to support spore germination. Inoculation was done by using one of three methods depending on the amount of available spores: the spatula method (Stakman *et al.* 1962), dusting with a mixed talcum powder (1:25 v/v), or by using a baby cyclone (Tervet and Cassell 1951). The inoculated plants were kept in a moist chamber for 24 hours to allow spore germination and infection. The incubated plants were then removed and placed on benches in the greenhouse at a temperature of 20 ± 2°C for leaf rust and 25–28°C for stem rust. Illumination was by means of lamps of about 1000 foot candles (Stubbs 1988). After 6–7 days, flecks (yellow colored) appeared, and by the end of 12–15 days, pustules were in full development and ready for harvesting.

Purification and Isolation

Spores from 4–5 selected single pustules were separately harvested, thus forming 4–5 isolates. Each isolate was separately multiplied on a susceptible check, as mentioned above.

Differential System

Spores harvested from each isolate after multiplication were used to inoculate seedlings of the differentials. For leaf rust, the 12 standard differentials suggested by Johnson and Browder (1966), with 17 lines carrying single genes (Samborski 1985; Long and Kolmer 1989), were used (Table 3). For stem rust, the 12 standard differentials suggested by (Stakman *et al.* 1962), together with 19 lines carrying single genes (Roelfs and Martens 1988), were employed (Table 4). These lines were used to determine the effective resistance genes for each country and for the region, and to help identify the present virulence/avirulence formula as a new concept or method for detecting the pathogen types in a specific area. After the full development of pustules on the differentials, the infection type of each differential was recorded. Seven infection types with corresponding varietal reactions were used, where the resistant reaction was *0;*, 0, 1 and 2, and the susceptible reaction was 3, 4 and X (Stakman *et al. 1962*).

Table 3. Leaf rust standard differential varieties and monogenic lines used for race identification and virulence analysis.

No.	Genotype	Tester	*Lr* gene	Source
1	Malakof	–	–	–
2	Carina	–	–	–
3	Brevit	–	–	–
4	Webster	–	–	–
5	Loros	–	–	–
6	Mediterranean	–	–	–
7	Hussar	–	–	–
8	Democrat	–	–	–
9	Lee	–	–	–
10	Wester	–	–	–
11	Sinvalocho	–	–	–
12	Waban	–	–	–
13	Tc^6 × Centenario	RL 6003	*Lr 1*	Malakof
14	Tc^6 × Webster	RL 6016	*Lr 2a*	Webster
15	Tc^6 × Loros	RL 6022	*Lr 2c*	Brevit
16	Tc^6 × Democrat	RL 6002	*Lr 3a*	Democrat
17	Tc^6 × Transfer	RL 6010	*Lr 9*	*T. umbellulatum*
18	Tc^6 × Exchange	RL 6005	*Lr 16*	Exchange
19	Tc^6 × Agent	RL 6064	*Lr 24*	*A. elongatum*
20	Tc^6 × St. 1.25	RL 6078	*Lr 26*	Imperial rye
21	Tc^6 × Aniversario	RL 6007	*Lr 3ka*	Klein Aniversario
22	Hussar (W 976)	RL 6053	*Lr 11*	Hussar
23	Tc^6 × Klein Lucero	RL 6008	*Lr 17*	Klein Lucero
24	Tc^6 × Teren	RL 6049	*Lr 30*	Terenzio
25	Tc^6 × Exchange	RL 6004	*Lr 10*	Lee
26	Tc^6 × Africa 43	RL 6009	*Lr 18*	Africa
27	Tc^6 × RL 5406	RL 6043	*Lr 21*	*T. tauschii*
28	Tc^6 × Lee 310	RL 6012	*Lr 23*	Gabo
29	$Thatcher^6$		*Lr 22b*	$Thatcher^6$

RL = Rust Laboratory Number. Canada Department of Agriculture.

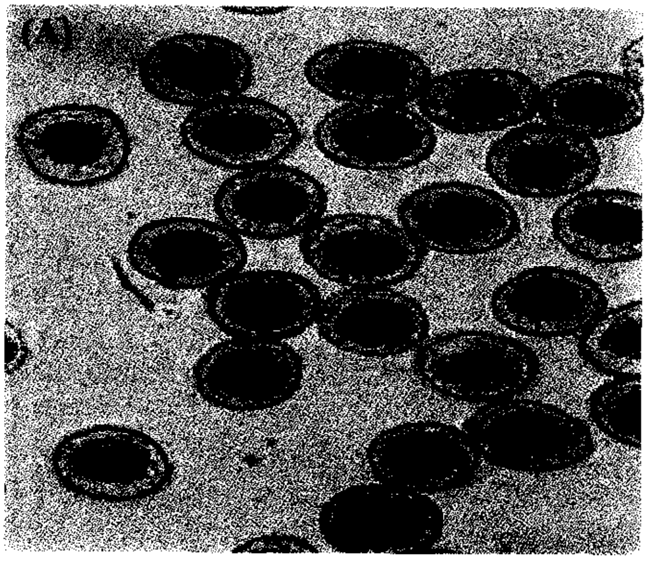
Table 4. Stem rust standard differential varieties and monogenic lines used for race identification and virulence analysis.

No.	Genotype	Tester	*Sr* gene	Source
1	Little Club	–	*LC*	–
2	Marquis		*7b, 18, 19, 20, x*	–
3	Reliance	–	*5,16,18,20*	–
4	Kota	–	*7b, 18, 19, 28, Kt'2'*	–
5	Arnutka	–	*9d,a*	–
6	Mindium	–	*9d,a,b*	–
7	Spelman	–	*9d,a,b*	–
8	Kubanka	–	*9g,c*	–
9	Acme	–	*9g,d*	–
10	Einkorn	–	*21*	–
11	Vernal	–	*9e*	–
12	Khapli	–	*7a, 13, 14*	–
13		I*Sr 5*-Ra	*Sr 5*	Reliance
14		Einkorn	*Sr 21*	*Triticum monococcum*
15		Vernstein	*Sr 9e*	Vernstein
16		I*Sr 7b*-Ra	*Sr 7b*	Marquis
17		I*Sr 11*-Ra	*Sr 11*	Lee
18		I*Sr 6*-Ra	*Sr 6*	Red Egyptian
19		I*Sr 8*-Ra	*Sr 8a*	Red Egyptian
20		CnS*Sr* 99	*Sr 9G*	Lee
21		W2691 *Sr Tt-1*	*Sr 36*	*T. timopheevii*
22		W2691 *Sr 9b*	*Sr 9b*	Kenya 117A
23		Bt*Sr 30* Wst	*Sr 30*	Webster
24		CS (Hope 78)	*Sr 17*	Renown
25		I*Sr 9d*-Ra	*Sr 9d*	Hope
26		Bt*Sr Gt Gt*	*Sr Gt*$^+$	Gamut
27		Bt*Sr 24* A9	*Sr 24*	*Agropyron elongatum*
28		LC*Sr 25* Ars	*Sr 25*	*A. elongatum*
29		Eagle	*Sr 26*	*A. elongatum*
30		W2691 *Sr 27*	*Sr 27*	Imperial rye
31		Pusa *Sr 29* Edch	*Sr 28*	

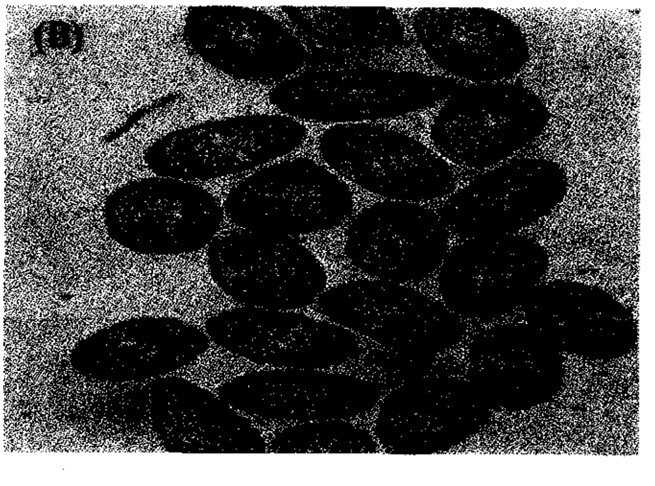
Spore Trapping

Seven-day Burkard spore trap samplers were installed at seven locations in the region: three in Egypt (Nubaria, Sids and Shandaweel), three in Ethiopia (Debre Zeit, Holetta and Kulumsa), and one in Sudan (New Halfa). The samplers were operating all year round beginning with January 1993 to August 1997. They were set up in such a way that the orifices of the traps were 150 cm aboveground and adjusted to run at a suction rate of 10 liters per minute (14.4 cm^3 of air per day) (Fig. 2). The urediospores trapped per day were counted either from the whole 48 mm length of the adhesive tape exposed in a day (in 1993 and 1994) or calculated from samples of 15 microscopic fields on the 48 mm length tape section exposed in a day (since 1995). A Gelvatol solution was used as adhesive (35 g Gelvatol, 50 ml glycerol or 40 ml lactic acid, 29 g phenol + 100 ml distilled water). Spore catches in one cubic meter of air sucked by the trap were calculated from the number of spores trapped each day. Spore catch per cubic meter of air was finally adjusted by multiplying by 0.7 since the trap had 70% efficiency. Trapped spores of leaf and stem rusts were identified based on their morphological characteristics as seen under the microscope and recorded separately (Fig. 3A and B).

Fig. 2. Burkard seven-day recording volumetric spore trap.



Leaf rust urediospores, *Puccinia recondita*



Stem rust urediospores, *Puccinia graminis*

Fig. 3. Leaf rust urediospores (A) tend to be more spherical without conspicuous, loose epidermal tissue at the margins. Stem rust urediospores (B) tend to be elongate, or oval to egg-shaped, with loose epidermal tissue that is conspicuous at the margins.

RESULTS AND DISCUSSION

Nile Valley Red Sea Wheat Rust Trap Nursery (NVRSWRTN)

First Disease Incidence and Movement

The first incidence of the disease was observed on plants of the NVRSWRTN planted at the different sites in the region, or on wheat plants in the vicinity of the nursery.

Leaf Rust: Information on first incidence of leaf rust (*Puccinia recondita*) in the region is shown in Table 5. The earliest first incidence of the disease in Egypt was recorded on 15 January in 1997 at Nubaria. There were no differences in the timing of the first incidence between the other sites, and no significant development of leaf rust was reported. This may be due to the overwhelming infection with yellow rust that year. In 1994, the disease was recorded as early as 7 February and the time difference between the first appearance at Nubaria in the north and Shandaweel in the south was 13 days. The weather conditions were favorable for disease development. The disease hit most of the promising high-yield trials and many of them were cancelled. The largest difference (70 days) between the first appearance in the north (Nubaria, 15 January) and south (Mataana, 25 March) was recorded in 1997. Also, a large difference of 53 days was reported between the north (Nubaria, 17 February) and south (Shandaweel, 10 April) in 1996. This may be considered as an indicator of the progress of the disease from north to south in Egypt. In general, March may be considered the month of the first occurrence of leaf rust in Egypt.

Table 5. First leaf rust disease incidence in Egypt, Ethiopia and Sudan, 1993–1997.

Country/Location	Year				
	1993	1994	1995	1996	1997
Egypt					
Nubaria	April 10	February 7	March 15	February 17	January 16
Zarzoura	April 10	February 15	March 7	March 5	March 10
Sakha	April 5	February 14	March 25	March 5	March 10
Ismailia	–	February 15	–	March 10	March 7
Sids	April 12	February 15	March 15	March 10	March 10
Shandaweel	April 15	February 20	March 25	April 10	March 25
Mataana	–	–	–	–	March 25
Ethiopia					
Kulumsa	August 24	September 9	August 14	–	–
Holetta	September 4	–	October 5	August 10	–
Adet	August 20	–	September 18	–	–
Ambo	–	October 19	August 5	August 14	–
Sinana	–	–	–	October 10	–
Debre Zeit	August 11	October 15	October 15	–	–
Alemaya	–	–	–	September 2	–
Sudan					
New Halfa	December 25	–	–	–	–

In Ethiopia, the earliest first incidence of leaf rust was recorded on 5 August 1995 at Ambo. The largest difference (56 days) in first incidence was recorded between Ambo in the north (14 August) and Sinana in the south (10 October) in 1996. However, there is also a recorded difference of 40 days between the first incidence in the south (9 September) and north (Ambo, 19 October) in 1994. Accordingly, there is no indication of disease progress, i.e., whether the disease is from south to north or vice versa. However, the highest frequency of first leaf rust incidence is in August.

Information on the first incidence of leaf rust in New Halfa, Sudan, is available only for one year. The earliest incidence recorded during the field survey conducted within the present study (1993–1997) was on 25 December 1995.

No data on first incidence of leaf rust was received from Yemen.

Stem Rust: Information on the first incidence of stem rust (*Puccinia graminis*) in the region is presented in Table 6. The earliest first disease incidence in Egypt was on 10 March 1994 at Nubaria. There exists no sharp graduation in the progress of the disease from north to south or vice versa. A difference of 30 days in first incidence was recorded in 1995 between Mataana in the south (25 March) and Nubaria in the north (25 April), as well as in 1996 between Nubaria (25 March) and Shandaweel in the south (25 April). The frequency of first stem rust incidence in Egypt indicates that the disease starts to develop by mid-April.

Table 6. First stem rust disease incidence in Egypt, Ethiopia and Sudan, 1993–1997.

Country/Location	Year				
	1993	1994	1995	1996	1997
Egypt					
Nubaria	April 10	March 10	April 25	March 25	April 1
Zarzoura	April 10	April 8	–	April 5	March 31
Sakha	April 5	–	April 20	April 30	April 5
Ismailia	–	April 10	April 20	April 10	April 15
Sids	April 12	April 10	–	March 25	March 25
Shandaweel	April 15	March 30	March 25	April 25	April 10
Mataana	–	–	March 25	–	March 25
Ethiopia					
Kulumsa	August 24	September 18	August 14	August 27	–
Holetta	September 21	October 8	October 5	–	–
Adet	August 20	–	September 18	August 28	–
Ambo	–	September 29	August 26	August 14	–
Sinana	–	–	–	October 1	–
Debre Zeit	September 9	August 25	August 21	August 12	–
Alemaya	–	–	–	September 2	–
Sudan					
New Halfa	December 25	–	–	–	–

In Ethiopia, the earliest first stem rust incidence was recorded on 12 August 1996. In most years, the disease seems to appear first in Debre Zeit. The highest frequency of disease appearance in Ethiopia is in August.

As in leaf rust, the first incidence of stem rust in Sudan is in the last week of December.

No data is available from Yemen.

Sources of the Primary Inoculum: Two cycles were recorded for the prevalent wind direction in Africa and Asia. Generally, the wind comes from the north, northwest and northeast during January–July, as shown in Fig. 4. During July–January, the wind is usually from the south, southeast to north and, sometimes, from north to south (Fig. 5). These directions could be attributed to the presence of high-pressure zones in certain territories from which the wind direction is determined, as shown in the following.

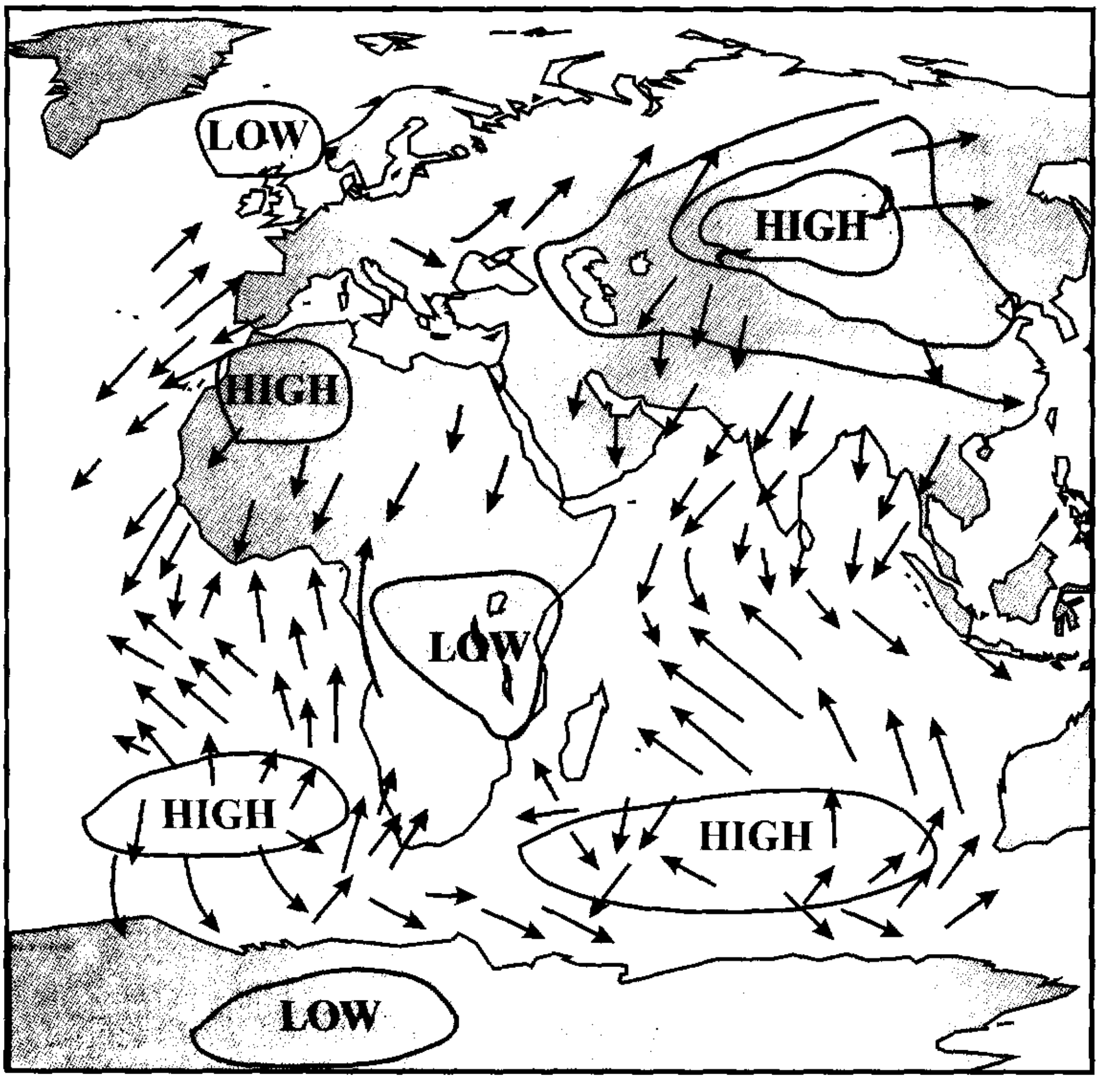


Fig. 4. The prevalent occurrence of wind direction during January–July in Africa and Asia.

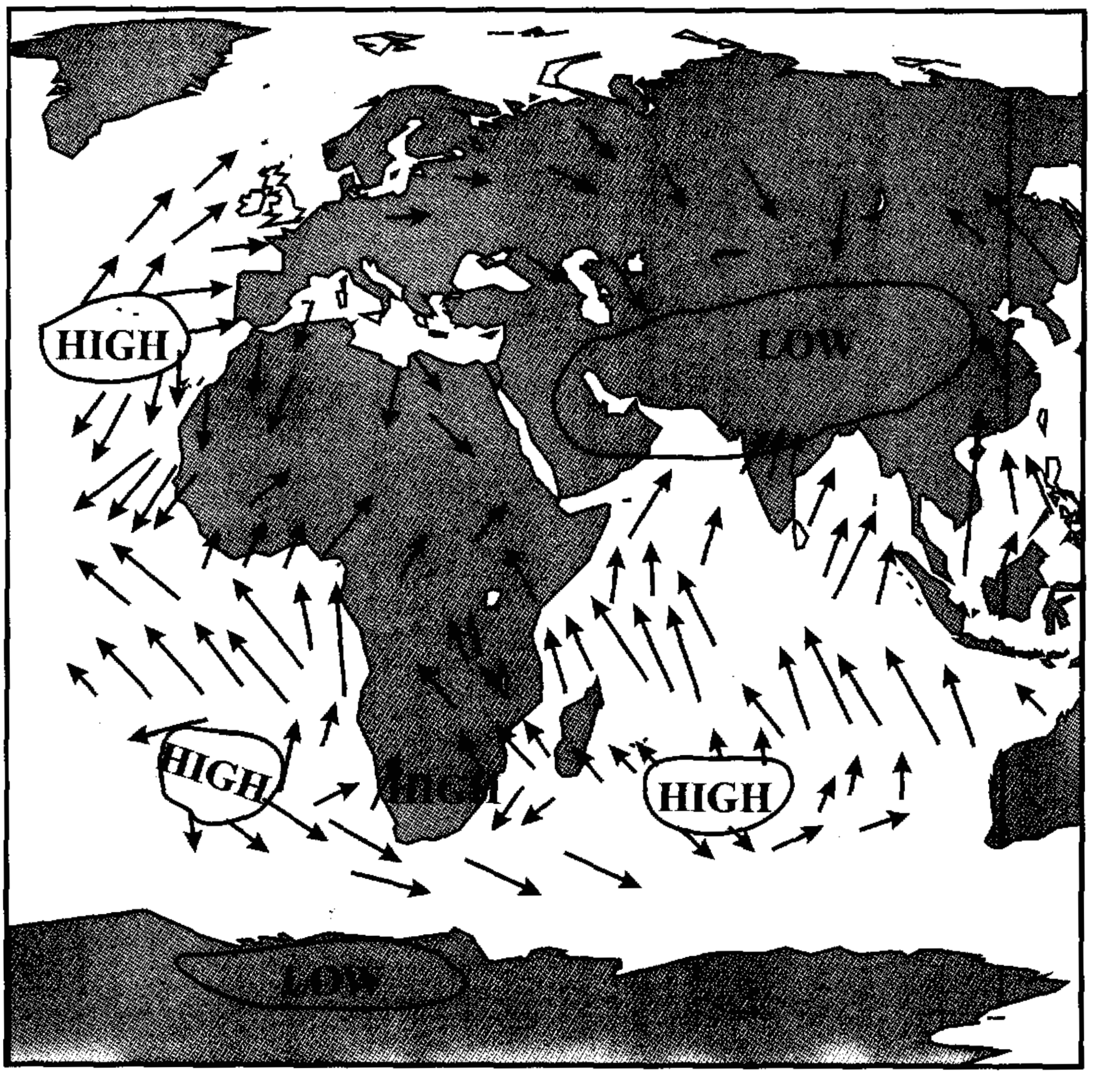


Fig. 5. The prevalent occurrence of wind direction during July–January in Africa and Asia.

1. Egypt: During the growing season, wind occurs mainly in November to June, usually from north, northeast and northwest. The weather conditions during the growing season are mild and temperature can be considerable.

Results of the studies on the effect of temperature on the viability of leaf rust urediospores in Egypt indicated that the urediospores lost their viability when stored for 45 days at 20°C and after 39 days when stored at 30°C. At 40°C, the spores were unable to germinate after 6 days (Nazim 1971; Abdel-Hak *et al.* 1972). Germination capacity of the spores exposed to outdoor conditions during April–May dropped sharply after 18 days and was zero after 24 days.

It seems quite reasonable to assume that the primary inoculum comes from the northern countries due to the main wind direction in Egypt during the wheat-growing period, usually from north, northeast and northwest.

2. Ethiopia: Wheat is grown in two cycles in Ethiopia: November–May and June–December. Different agroclimatic conditions exist in Ethiopia and in the neighboring African countries. Consequently, the effect of the presence of wheat on the availability of alternative hosts throughout the year is to be expected. This means that it is unlikely that the inoculum arrives from outside Ethiopia. More information on the alternate/alternative hosts, on the wheat-growing seasons in the neighboring countries, and on the wind direction is still needed.

3. Sudan: The wheat-growing season in Sudan is short (November to March), and temperature during the summer is very high, which gives no chance for urediospores to over-summer. Therefore, it is logical to believe that the primary inoculum, mainly in New Halfa area, comes from outside, perhaps from Yemen or Ethiopia, or from other neighboring African countries.

4. Yemen: Wheat is grown in all seasons in Yemen, and stem rust was reported to be present at the seedling stage in October.

Wheat leaf rust is widespread throughout Europe, and is considered a significant disease in many eastern and western European countries. Park and Felsentein (1996) detected that there was some migration of leaf rust from northern countries to western Europe. The same phenomenon was reported by Limpert (1987) on migration and long-distance dispersal of wind-borne cereal diseases in Europe (e.g. *Erisiphe graminis* f.sp. *hordei* and *Puccinia striiformis*). Zadoks (1965) pointed out to the importance of studying the populations of such plant pathogens on a European scale.

In general, it may be concluded that the inoculum exists throughout the year in the Nile Valley countries and Yemen. Also, there seems to be no clear trend between the time of first disease incidence and the development of rust diseases in the countries. The question on the primary inoculum for these diseases and its pathways is still unanswered. More studies, support and cooperation between the African and Red Sea countries are needed.

Performance of Lines and Cultivars in NVRSWRTN, and Sources of Resistance

Results on the performance of the monogenic lines and cultivars in the NVRSWRTN at different sites in the region during the 1992/93–1996/97 growing seasons are presented in Appendix 1 for leaf rust and 2 for stem rust. In total, there were 22 planting sites, but not all were planted or evaluated every growing season. Failure to plant or to evaluate was due to several unpredictable factors, such as over-flooding, grazing by animals or insect damage of the nursery at some sites in some years. At two sites, Holetta (Ethiopia) and Dhamar (Yemen), scoring the infection type (leaf or stem rust) was difficult and unreliable. This was due to the annual heavy infection of the nursery by septoria blotch in the former site and by yellow rust in the latter.

A summary of the average coefficient of infection and the coefficient of infection (ACI and CI), derived from Appendixes 1 and 2, is presented in Tables 7, 8 and 9 for leaf rust, and Tables 10, 11 and 12 for stem rust. To highlight the performance of the lines and cultivars of the NVRSWRTN, as well as the performance of the checks with the wild relative entries, the isogenic lines, and the commercial cultivars, each group was presented in a different table and discussed separately.

Table 7. Performance† of the checks and wheat wild relatives in the NVRSWRTN against leaf rust (*Puccinia recondita*) at different locations in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Cultivar/Line	ACI, country				ACI, region
	Egypt	Ethiopia	Sudan‡	Yemen	
Triticum spelta saharense (check)	57.5	29.8	22.5	33.0	35.7
Little Club (check)	50.0	8.7	33.0	21.6	28.3
Triticum boeoticum No. 600674	44.9	6.2	23.3	14.0	22.1
T. boeoticum No. 600742	42.5	5.4	23.3	16.2	21.9
T. dicoccoides No. 600363	27.7	11.3	23.3	21.8	21.0
T. dicoccoides No. 600375	33.3	10.0	13.0	15.2	17.9
T. dicoccoides No. 600679	41.2	17.8	10.3	26.0	23.8
T. dicoccoides No. 600715	49.1	22.3	22.5	27.6	30.9

† Mean average coefficient of infection (ACI) over sites and years.
‡ Mean coefficient of infection (CI) over years.

Table 8. Performance† of *Lr* isogenic lines in the NVRSWRTN against leaf rust (*Puccinia recondita*) at different locations in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Cultivar/Line		ACI, country				ACI, region
		Egypt	Ethiopia	Sudan‡	Yemen	
Thatcher^6 × Webster	*Lr 2a*	20.4	8.6	11.5	1.8	10.6
Thatcher^6 × Hussar	*Lr 11*	25.0	3.7	4.8	2.0	8.9
Thatcher^6 × Transfer	*Lr 9*	8.4	8.9	19.0	2.0	9.6
Thatcher^6 × Klein Lucero	*Lr 17*	6.7	5.3	9.0	0	3.5
Thatcher^6 × Africa 43	*Lr 18*	7.8	18.6	2.1	3.2	7.9
Thatcher^6 × RL 5406	*Lr 21*	13.5	1.7	7.5	1.2	6.0
Thatcher^6 × Lee 310	*Lr 23*	23.1	12.9	10.5	9.6	14.0
Agent	*Lr 24* & *Sr 24*	35.8	13.8	13.8	8.0	17.9
Tc^6 × St. 1.25	*Lr 26* & *Sr 31*	28.2	2.7	16.1	0.8	11.9

†, ‡ See Table 7.

Table 9. Performance† of the commercial cultivars in the NVRSWRTN against leaf rust (*Puccinia recondita*) at different locations in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Cultivar/Line	ACI, country				ACI, region
	Egypt	Ethiopia	Sudan‡	Yemen	
Giza 155	21.5	12.5	16.3	13.1	15.9
Giza 157	8.9	0.7	2.4	0.4	3.1
Giza 160	45.9	15.7	12.7	5.1	19.9
Giza 162	7.5	1.2	6.2	0.4	3.8
Giza 163	15.6	1.1	17.5	2.4	9.2
Giza 164	11.0	1.1	8.2	0.4	5.2
Giza 165	8.9	0.2	7.8	3.2	5.0
Sakha 8	5.1	0.7	5.8	2.4	3.5
Sakha 69	5.0	3.0	5.8	7.2	5.3
Sakha 92	13.8	0.5	4.0	0.4	4.7
Gemmeiza 1	10.9	10.9	3.0	3.6	7.1
Gemmeiza 3	5.3	19.3	1.5	0.4	6.6
Beni Suef 1	3.9	10.1	6.4	9.8	7.6
Sohag 1	8.2	9.3	2.5	10.2	7.6
Sohag 2	8.2	9.8	2.7	11.2	8.0
Sohag 3	10.8	11.7	19.0	18.4	15.0
Debeira	7.3	1.5	3.8	2.4	3.8
Condor	6.2	3.2	8.0	0.2	4.4
Condor 'S'	2.2	6.3	1.8	0	2.6
El-Neilain	9.3	14.1	13.5	10.0	11.7
Baladi	25.7	1.9	16.5	0.3	11.1
Enkoy	9.9	10.6	0.5	0	5.3
K 6890-Bulk	5.4	13.7	0.3	1.0	5.1
Dashen	2.8	4.1	0.4	0.1	1.9
ET-13	9.0	3.1	1.2	4.8	4.5
K 6295-4A	6.7	3.8	1.0	0.1	2.9
C.T. 71/CII	5.1	7.3	0.5	0.4	3.3
Bohai	11.1	8.0	1.8	0.5	5.4
Cocorit 71	6.4	13.5	6.5	0.1	6.6
DZ 04-118	8.5	22.2	0.8	0	7.9
Mokhtar	19.6	1.7	1.5	0.2	5.8
Aziz	11.9	4.3	7.5	0.2	6.0
Marib 1	1.0	2.3	1.5	0.2	1.3

†, ‡ See Table 7.

Table 10. Performance† of the checks and wheat wild relatives in the NVRSWRTN against stem rust (*Puccinia graminis*) at different locations in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Cultivar/Line	ACI, country				ACI, region
	Egypt	Ethiopia	Sudan‡	Yemen	
Triticum spelta saharense (check)	28.8	21.0	52.0	31.8	33.2
Little Club (check)	28.6	31.8	47.0	34.0	35.4
Triticum boeoticum No. 600674	7.2	12.9	22.8	0.1	12.4
T. boeoticum No. 600742	3.3	24.8	26.0	0.9	14.3
T. dicoccoides No. 600363	0.4	4.9	26.0	0.1	7.9
T. dicoccoides No. 600375	0.8	7.4	24.0	-	10.7
T. dicoccoides No. 600679	1.7	8.4	45.0	-	18.4
T. dicoccoides No. 600715	0	12.5	20.0	-	10.8

†, ‡ See Table 7.

Table 11. Performance† of *Sr* isogenic lines in the NVRSWRTN against stem rust (*Puccinia graminis*) at different locations in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Cultivar/Line		ACI, country				ACI, region
		Egypt	Ethiopia	Sudan‡	Yemen	
Prelude × Reliance	*Sr 5*	0.1	10.0	11.3	0.2	5.4
Line Dsel	*Sr 6*	0.5	12.3	22.5	1.1	9.1
Vernstein	*Sr 9e*	0.2	23.0	16.8	6.0	11.6
Line AG	*Sr 11*	6.9	14.3	12.4	1.5	8.8
Einkorn	*Sr 21*	0.4	19.0	24.4	7.3	12.8
LC *Sr 25* Ars	*Sr 25*	0.1	17.7	32.0	14.0	16.0
Eagle	*Sr 2* and *Sr 26*	1.5	8.6	14.0	19.7	11.0
W2691 *Sr 28 Kt*	*Sr 28*	2.6	23.4	38.8	16.2	20.3
Gamut	*Sr Gt*	0.3	2.7	6.8	13.3	5.8
Triticum timopheevii	*Sr Tt-1 (36)*	0.3	15.4	18.8	4.7	9.8

†, ‡ See Table 7.

Table 12. Performance† of the commercial cultivars in the NVRSWRTN against stem rust (*Puccinia graminis*) at different locations in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Cultivar/line	ACI, country				ACI, region
	Egypt	Ethiopia	Sudan‡	Yemen	
Giza 155	0.3	0	1.8	5.4	1.9
Giza 157	0	4.9	10.0	18.9	8.5
Giza 160	2.7	6.3	11.6	0.5	5.5
Giza 162	2.4	12.9	5.2	10.1	7.7
Giza 163	0.2	7.2	19.0	0.9	6.8
Giza 164	0.9	8.7	10.0	4.2	6.0
Giza 165	0.2	18.9	8.2	12.2	9.7
Sakha 8	0.6	8.8	16.1	4.8	7.6
Sakha 69	0.9	5.8	9.0	3.4	4.8
Sakha 92	0.1	4.4	4.8	4.9	3.6
Gemmeiza 1	0	7.6	9.6	8.1	9.3
Gemmeiza 3	0.1	9.1	13.2	16.1	9.6
Beni Suef 1	0.3	15.0	26.8	11.6	13.4
Sohag 1	0	15.9	26.0	13.1	13.8
Sohag 2	0.5	24.5	34.0	15.9	18.7
Sohag 3	1.2	21.9	38.8	10.1	18.0
Debeira	1.4	1.4	0.5	12.2	3.9
Condor	0.4	2.8	1.3	16.1	5.2
Condor 'S'	0.7	4.5	2.0	4.1	2.8
El-Neilain	0.4	13.9	9.3	0.5	6.0
Baladi	19.5	4.5	12.2	0.1	9.1
Enkoy	0.1	14.2	0.6	16.1	7.8
K 6890-Bulk	0.3	0.3	0.2	8.2	2.3
Dashen	0.8	5.4	0.2	0.5	1.7
ET-13	0.3	1.1	0.3	1.8	0.9
K 6295-4A	0.7	0.4	0.2	6.6	2.0
C.T. 71/CII	0.6	1.0	4.8	5.9	3.4
Bohai	0.5	3.8	4.4	1.0	3.1
Cocorit 71	1.6	1.8	4.4	6.2	3.5
DZ 04-118	0.9	10.6	6.8	4.2	5.6
Mokhtar	0.3	1.1	13.0	0.1	3.6
Aziz	0.1	6.7	8.5	0.2	3.9
Marib 1	1.1	6.3	6.3	0.2	3.5

†, ‡ See Table 7.

Leaf Rust: All checks and wheat wild relatives, except Little Club, *T. boeoticum* No. 600674, *T. boeoticum* No. 600742 and *T. dicoccoides* No. 600375 in Ethiopia, showed a high ACI of more than 10 (Table 7). The highest infection was in Egypt on *T. spelta saharense* (ACI = 57.5) and Little Club (ACI = 50.0). In general, all entries showed a relatively high infection in the region, with an ACI ranging from 17.9 to 35.7. This indicates that leaf rust developed well during the growing seasons that were evaluated, enabling testing and selecting sources of resistance to the disease.

Results on the performance of the isogenic lines against leaf rust indicated that the highest ACI or CI was recorded on *Lr 24* & *Sr 24* in Egypt (35.8), *Lr 18* in Ethiopia (18.6), *Lr 9* in Sudan (19.0), and *Lr 23* in Yemen (9.6) (Table 8). In the region as a whole, the most susceptible lines were *Lr 24* & *Sr 24*, *Lr 23*, *Lr 26* & *Sr 31*, and *Lr 2a*, with 17.9, 14.0, 11.9 and 10.6, respectively. The isogenic lines with gene *Lr 17* had an ACI of less than 10, and thus can be considered as a source of resistance for leaf rust at the adult stage in the region and in any of the countries in this study.

Out of the 33 tested commercial cultivars, 5 cultivars were resistant in Egypt, 16 in Ethiopia, 18 in Sudan and 25 in Yemen, with ACI or CI of less than 5 (Table 9). Cultivars Giza 157, Giza 162, Giza 165, Sakha 8 and Sakha 69 from Egypt; Dashen, ET-13, K 6295-4A and C.T. 71/CII from Ethiopia; Debeira, Condor and Condor 'S' from Sudan; and Marib 1 from Yemen were resistant in the region and in any one of the four countries (ACI less than 10).

Stem Rust: All checks and wheat wild relatives showed high infection (more than 20.0 CI) with stem rust in Sudan (Table 10). The highest infection in the other countries was exhibited by Little Club in Yemen (34.0) and Egypt (28.6), and by *T. boeoticum* No. 600742 (24.8) in Ethiopia. In the region, stem rust infection ranged from 7.9 to 35.4 ACI, with the highest on Little Club (35.4) and *T. spelta saharense* (33.2).

In Egypt, all tested isogenic lines showed low infection (0.1–6.9 ACI) with stem rust, the highest being on *Sr 11* (Table 11). In Ethiopia, all lines, except *Sr Gt*$^{+}$, were highly infected (8.6–23.4 ACI). In Sudan, all isogenic lines showed a high infection (11.3–38.8 CI), and only *Sr Gt*$^{+}$ showed a relatively low infection (6.8 CI). In Yemen, only 4 lines, namely, *Sr 5*, *Sr 6*, *Sr 11* and *Sr Tt-1* (36), showed a low infection (less than 5 ACI). Not a single line performed well (i.e., with less than 10 ACI) in the whole region and in all the tested countries at the same time.

Out of the 33 commercial cultivars tested, only one (Baladi) showed a high infection (more than 5 ACI) with stem rust in Egypt (Table 12). In the other countries, 15, 13 and 16 cultivars showed a low infection rate of less than 5 ACI or CI in Ethiopia, Sudan and Yemen, respectively. Fifteen cultivars performed well (less than 10 ACI) in the region and in each of the tested countries (Giza 155, Giza 164, Sakha 69, Sakha 92 and Gemmeiza 1 from Egypt; K 6890-Bulk, Dashen, ET-13, K6295-4A, C.T. 71/CII, Bohai and Cocorit 71 from Ethiopia; Condor 'S' from Sudan; and Aziz and Marib from Yemen). In the region, 7 commercial cultivars (Sakha 69, Condor 'S', Dashen, ET-13, K 6295-4a, C.T. 71/CII, and Marib 1) had excellent performance against leaf and stem rusts, which also did not exceed 10 ACI in any country.

Conclusion

The above results have led to the assumption that leaf rust inoculum in Egypt is exogenic and its pathway is from north to south, whereas the inoculum in Ethiopia is endogenic. In Sudan, it seems that the primary inoculum comes from outside the country; perhaps from Yemen, due to the presence of spores all year round, or from other neighboring African countries. As for stem rust, the inoculum in Egypt may be coming from north or south depending on wind direction. In Ethiopia and Yemen, it is present all year round due to the two-cycle cropping system. The most effective leaf and stem rust genes at both the seedling and adult stages in the region and in any of the tested countries are *Lr 17* and *Sr Gt*[1].

The cultivated wheat germplasm showed good levels of resistance against leaf rust. The lowest ACI was found on varieties Giza 157, Giza 162, Giza 165, Sakha 8 and Sakha 69 (Egypt); Dashen, ET-13, K 6395-4A and C.T. 71/CII (Ethiopia); Debeira, Condor and Condor 'S' (Sudan); and Marib 1 (Yemen). As for stem rust, the cultivars with the lowest ACI were Giza 155, Giza 164, Sakha 69, Sakha 92 and Gemmeiza 1 (Egypt); K6890-B, Dashen, ET-13, K6295-4A, C.T. 71/CII, Bohai and Cocorit 71 (Ethiopia); Condor 'S' (Sudan); and Aziz and Marib 1 (Yemen). Seven cultivars performed well against both diseases in the region: Sakha 69, Condor'S', Dashen, ET-13, K6295-4A, C.T. 71/CII and Marib 1.

IDENTIFICATION OF PATHOTYPES AND SOURCES OF RESISTANCE

For pathotype identification and virulence analysis of the rust populations in the region, 663 leaf rust samples (445 Egypt, 107 Ethiopia, 79 Sudan and 32 Yemen) and 715 stem rust samples (431 Egypt, 146 Ethiopia, 102 Sudan and 36 Yemen) were used (Table 13).

Table 13. Number of wheat leaf and stem rust samples collected in Egypt, Ethiopia, Sudan and Yemen for race identification and virulence analysis, 1992/93–1996/97.

Country	*Leaf rust*						*Stem rust*					
	92/93	93/94	94/95	95/96	96/97	Total	92/93	93/94	94/95	95/96	96/97	Total
Egypt	45	156	35	154	55	445	56	132	42	81	120	431
Ethiopia	30	19	17	12	29	107	22	39	32	27	26	146
Sudan	35	25	12	7	–	79	14	56	10	22	–	102
Yemen	4	6	12	7	3	32	–	18	4	2	12	36
Total	114	206	76	180	87	663	92	245	88	132	158	715

Leaf Rust Pathotypes and Sources of Resistance to the Disease

Table 14 shows the frequency of leaf rust pathotypes in the region. There were 19 pathotypes identified in Egypt, 16 in Ethiopia, 5 in Sudan and 6 in Yemen.

In Egypt, pathotypes 57 and 77 occurred in every growing season. Pathotypes 77, 12, 57 and 144 prevailed with high frequencies (94.6, 35.5, 34.4 and 32.5%, respectively). Pathotypes 4, 7, 117, 130, 147, 149, 151, 158, 192 and 213 occurred in only one season and with low frequencies (1.1–7.0%).

Table 14. Frequency % of physiologic pathotypes of leaf rust in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Patho-	Egypt					Ethiopia					Sudan					Yemen				
type	92/93	93/94	94/95	95/96	96/97	92/93	93/94	94/95	95/96	96/97	92/93	93/94	94/95	95/96	96/97	92/93	93/94	94/95	95/96	96/97
4			1.5																	
6									3.1											
7			1.5																	
12	28.6	35.5	1.5			28.5	50			10		64				100		52.4		
21		1.1	1.5						3.1	10										
51									3.1											
52									3.1											
54																				10
57	21.3	34.4	4.2	4.2	2.7		20		21.9			16								
77	7.1	20.4	70.8	91.6	94.6	14.3	24		43.8	80										80
117			1.5						3.1											
122									3.1									34.8		
129		1.1	4.2						3.1											
130					2.7															
144	32.5	2.1	4.2			14.3	4		3.1		100	8		100						
147		1.1																		
149			1.5						3.1											
151		2.2				32.9	2					4								
155		1.1	1.5																	
158	3.5																			
167									3.1								12.8			
184			3.8	4.2						10										10
192	7.0																			
206												4								
213			1.5																	
218									3.1											
221																				
223		1.0	1.3																	

In Ethiopia, pathotype 77 was found in four seasons, and pathotypes 12 and 144 in three. The highest frequencies were recorded for pathotype 77 (80%), pathotype 12 (50%), and pathotype 151 (32.9%). The pathotypes registered in Ethiopia for one season were 6, 51, 52, 117, 122, 129, 149, 167, 184 and 218.

In Sudan, pathotype 144 existed with 100% frequency in two seasons, 1992/93 and 1995/96. Pathotypes 12, 57, 151 and 206 each existed in one season, with pathotype 12 having the highest frequency of occurrence (64%) of the four, in 1993/94.

In Yemen, pathotype 12 was recorded in two seasons with high frequencies: 100 and 52.4%. The pathotypes identified in one season only were nos. 54, 77, 122, 167 and 184. Those with high frequencies were nos. 77 (80%) and 122 (34.8%).

No. 12 was the only pathotype identified in all four countries. The other most prevalent pathotypes in the region were nos. 57, 77, 144 and 151 in Egypt, Ethiopia and Sudan, and pathotype 77 in Egypt, Ethiopia and Yemen.

Results of the pathogenicity test at the seedling stage to identify sources of resistance to leaf rust are presented in Table 15. The test was conducted for three seasons on rust isolates collected in Egypt and Ethiopia in 1992/93, 1995/96 and 1996/97 and for one season for each of Sudan (1992/93) and Yemen (1996/97).

The highest effectiveness of leaf rust resistance genes in Egypt was demonstrated by *Lr's 21* (57.9%), *1*(51.8%), *22b* (43%), *18* (42.1%) and *26* (41.5%); in Ethiopia by *Lr's 1* (70%), *11* (65.8%), *21* (64.8%), *3ka* (62.3%) and *17* (57.7%); in Sudan by *Lr's 24* and *26* (100%), and *9, 17, 21* and *30* (80%); and in Yemen by *9, 21, 17* and *30* (80%), and *3ka* and *23* (70%).

The most effective leaf rust resistance genes in the region at the seedling stage were *Lr's 21* (70.6%), *17* (64.5%), *3ka* (60.1%), *30* (57.8%) and *11* (53.3%), with *Lr 21* being the most effective in the region and in each country. The leaf rust gene giving an adequate level of resistance at both the seedling and adult stages was *Lr 17*.

During the 1970s, Nazim (1971) reported that in Egypt, *Lr's 9, 13* and *19* were effective and induced resistance to races 77 and 184 at both the seedling and adult stages, while *Lr's 1, 2, 3* and *17* functioned only at the adult stage. During the 1980s, leaf rust genes *9, 13, 19, 21, 24* and *29* were highly effective against the Egyptian virulence at the seedling stage (Abdel-Hak *et al.* 1982). During the 1990s, the highest effectiveness was found on *Lr's 2a, 11, 18* and *21*, while *Lr's 2b, 9, 24, 23* and *3ka* gave reasonable resistance (Sherif *et al.* 1992; El-Daoudi *et al.* 1994, 1996a). Some of these genes (*Lr's 29, 9, 11, 18, 15* and *21*) are still effective in Egypt.

Johnson (1994) and Kebede *et al.* (1994) reported that *Lr's 17* and *26* reflected low severity against leaf rust infection under field conditions in Ethiopia. Saari (1996) reported that *Lr 26* became ineffective as early as 1985, yet it remained effective in India and Pakistan and some countries in Africa due to the absence of virulent isolates.

Table 15. Effectiveness % of leaf rust resistance genes in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Lr gene	Egypt				Ethiopia				Sudan	Yemen	Region
	92/93	95/96	96/97	Mean	92/93	95/96	96/97	Mean	96/97	96/97	
1	2.6	33.3	59.5	51.8	80	50.0	80	70.0	40	40	37.9
2a	2.6	16.7	13.5	10.9	20	50.0	20	30.0	0	0	10.2
2c	5.3	22.8	18.9	15.0	20	15.6	20	18.5	20	20	18.3
3	5.3	8.3	8.1	7.2	30	21.9	30	27.3	10	10	13.6
3ka	–	14.7	34.8	38.2	70	46.9	70	62.3	70	70	60.1
9	7.9	25.0	5.4	12.7	80	9.4	80	29.8	80	80	50.6
10	2.6	54.2	10.8	22.5	50	28.1	50	42.7	50	50	41.3
11	18.4	37.5	27.0	27.6	80	37.5	80	65.8	60	60	53.3
16	5.3	8.3	54.1	22.5	30	6.3	30	22.1	40	40	33.1
17	–	16.7	64.9	40.8	80	12.5	80	57.5	80	80	64.5
18	15.8	45.8	64.5	42.1	20	28.1	20	22.7	50	50	41.2
21	–	37.5	78.4	57.9	80	34.4	80	64.8	80	80	70.6
22b	-	29.5	56.8	43.0	30	6.3	30	22.1	50	50	41.2
23	10.5	25.0	32.4	22.6	60	25.0	60	48.3	70	70	52.7
24	5.3	16.7	78.4	33.4	20	12.5	20	17.5	100	10	40.2
26	–	20.8	62.2	41.5	70	18.8	70	52.9	100	10	51.1
30	5.3	29.2	29.7	21.4	70	9.4	70	49.8	80	80	57.8

Ahmed (1996) reported that in Sudan, some of the monogenic resistance lines are not reliable or useful in cultivated varieties due to their sensitivity to environmental conditions, particularly temperature. Roelfs *et al.* (1992) noted that under warm, humid conditions, some of the specific resistance genes, e.g., *Sr's 6, 10* and *17* are infective due to high temperature. Ahmed (1996) also reported that under Sudanese conditions, it is necessary to have stem and leaf rust-resistant varieties or lines that are not sensitive to temperature. The varieties possessing good combined resistance could be a good source of field resistance, e.g., Enkoy, K 6290-B and Et-13 (Ethiopia).

In Yemen, limited work on race analysis has been carried out outside the country. Information on leaf and stem rust and their epidemiology is rare.

Stem Rust Pathotypes and Sources of Resistance to the Disease

Table 16 shows the stem rust pathotypes identified in the region. The total number of stem rust pathotypes identified were 16 in each of Egypt and Ethiopia, 10 in Sudan and 9 in Yemen.

The most prevalent stem rust pathotype in Egypt was no. 11, occurring in five seasons, followed by no. 15, occurring in four seasons. Other pathotypes appearing in three seasons were no. 14, 17, 19 and 39. Pathotype 11 scored the highest frequency of occurrence (45.0%) followed by no. 9 (39.2%) and 123 (35%). Pathotypes that occurred in one season only during the survey years were 9, 10, 83, 117, 119, 123 and 218.

Pathotype 123 was the only stem rust pathotype occurring in Ethiopia in three seasons, while the identified pathotypes during two growing seasons were 10, 11, 14, 15, 19, 53 and 122, with the highest frequency (37) belonging to pathotype 10. The pathotypes detected in only one season were 9, 17, 24, 83, 117, 169 and 197. The highest frequency was 17.5 for pathotype 117 (Table 16).

In Sudan, only pathotype 15 occurred in three seasons. Other identified pathotypes that occurred in two seasons are nos. 11, 17, 24 and 123. Pathotypes that occurred in only one season are nos. 14, 19, 39, 53 and 122. The highest frequency (66.7%) was recorded by pathotype 123 followed by no. 11 (52.2%) and no. 15 (33.3%).

In Yemen, pathotypes 11, 14, 15 and 17 occurred in two seasons, while. 9, 24, 115 and 117 occurred in only one season. The highest frequency (35%) was that of pathotype 11 in 1996/97 followed by pathotype 19 (32%).

Six pathotypes (11, 14, 15, 17, 19 and 24) were common in all countries of the region. Pathotypes prevalent in three countries were 39, 53, 122 and 123 (in Egypt, Ethiopia and Sudan), and pathotype 117 (in Egypt, Ethiopia and Yemen).

Results of the pathogenicity test at the seedling stage to identify sources of resistance to stem rust are presented in Table 17. The test was conducted for four seasons on rust isolates collected in 1992/93–1996/97 in Egypt and Ethiopia and for two seasons on rust isolates collected in 1992/93 and 1993/94 in Sudan and Yemen.

Table 16. Frequency % of physiologic pathotypes of stem rust in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Patho-	Egypt					Ethiopia					Sudan					Yemen				
type	92/93	93/94	94/95	95/96	96/97	92/93	93/94	94/95	95/96	96/97	92/93	93/94	94/95	95/96	96/97	92/93	93/94	94/95	95/96	96/97
9	39.2					16.0														1
10					5		15.6	37												
11	1.7	6.7	41.0	35.5	45		18.8		33.3			23.4	52.2				33.3			35
14		20.4		10.0	5		2.8	22				8.8					20.2			4
15	7.0		26.0	11.2	25		9.5	12			33.3	5.1	28.7				15.1			17
17		4.7	19.3	21.8			12.5					11.7	9.3				10.8			2
19		14.3	10.0	11.8			15.6	12				11.9								32
24		9.3		8.2			6.3					8.8	6.0				4.2			
39			3.7	0.9	20							5.1								
53	1.6	16.3				25.5	6.3					8.8								
83		2.3						4												
115																				9
117		18.6				17.5											16.4			
119	15.5																			
122		4.7		0.6			6.3		4.2			5.1								
123	35.0					23.5	6.3	13			66.7		2.0							
169						5.9														
197						11.8														
218		2.7																		

Table 17. Effectiveness % of stem rust resistance genes in Egypt, Ethiopia, Sudan and Yemen, 1992/93–1996/97.

Sr gene	Egypt					Sudan			Ethiopia					Yemen			Region
	92/93	93/94	95/96	96/97	Mean	92/93	93/94	Mean	92/93	93/94	95/96	96/97	Mean	92/93	93/94	Mean	
5	60.6	13.3	17.3	20	27.8	66.1	41.2	53.6	88.2	34.4	25.6	59.4	46.9	–	36	36.0	41.1
6	4.3	5.0	21.8	25	20.9	33.3	–	33.3	32.3	–	16.7	21.2	23.4	15.4	21	18.2	24.4
7b	51.3	78.3	30.0	0	39.9	66.7	33.2	50.0	47.5	36.9	29.2	24.2	34.4	83.5	7	45.2	42.3
8a	26.3	45.0	23.7	20	28.7	66.7	35.3	50.0	32.3	40.6	2.1	18.2	23.3	46.7	14	30.3	33.1
9b	–	3.3	22.7	5	10.3	66.7	14.7	40.7	23.5	3.1	12.9	6.1	11.4	–	7	7.0	17.3
9d	–	–	20.9	0	10.4	66.7	–	66.7	29.4	–	18.8	12.1	20.1	–	6	6.0	25.8
9e	10.3	6.7	61.8	0	19.7	–	29.4	29.4	41.2	6.3	69.7	24.2	35.3	30.8	7	18.9	25.8
9g	15.4	–	10.9	6	10.4	33.3	–	33.3	41.1	–	6.3	12.1	19.8	–	4	4.0	16.8
11	2.6	11.6	12.1	25	14.5	66.7	8.8	36.2	23.3	6.3	25.0	15.2	17.4	15.4	10	12.7	20.2
17	–	3.3	4.6	0	2.6	–	2.9	2.9	–	6.3	6.3	9.1	7.2	23.1	8	15.5	7.0
21	–	–	6.4	5	5.7	–	9.4	9.4	32.4	–	10.4	27.3	23.3	–	10	10.0	12.1
24	15.4	8.3	20.0	15	19.8	–	8.8	8.8	29.4	18.8	27.1	21.2	24.1	–	18	18.0	17.6
25	11.1	1.6	5.5	10	7.1	66.7	8.8	37.7	47.5	6.2	6.3	12.1	18.0	–	6	6.0	17.2
26	68.4	6.6	23.7	25	30.9	33.3	5.9	19.6	52.9	3.1	37.5	33.3	31.7	–	31	31.0	28.3
27	4.8	3.3	8.2	0	4.1	–	–	–	11.8	–	18.8	12.1	14.2	23.1	9	16.1	11.5
29	45.3	18.3	23.6	5	23.1	100.0	23.5	61.7	64.7	18.8	12.5	12.1	27.0	23.1	6	14.6	31.6
30	74.4	4.7	23.7	60	40.7	66.7	8.8	37.7	94.1	12.9	22.9	24.2	38.5	–	14	14.0	32.7
36	53.0	3.3	11.8	–	22.7	66.7	8.8	37.7	70.6	–	10.4	9.1	30.0	–	4	4.0	23.6
Gt	53.9	73.3	70.9	10	54.5	–	47.5	47.5	85.9	71.9	60.4	36.4	63.6	53.8	27	40.0	51.5

The highest effectiveness against stem rust pathotypes collected in Egypt was 54.5, 40.7, 39.9, 30.9 and 28.7%, exhibited by *Sr's Gt*$^{+}$, *30, 7b, 26* and *8a*, respectively; for Ethiopia *Sr's Gt*$^{+}$ (63.6%), *5* (46.9%), *30* (38.5%), *9e* (35.3%) and *7b* (34.4%); for Sudan, *Sr's 29* (61.7%), *5* (53.6%), *7b* (50%), *8a* (50%) and *Gt*$^{+}$ (47.5%); and for Yemen *Sr's 7b* (45.2%), *Gt*$^{+}$ (40.4%), *5* (36%), *8a* (30.3%) and *9e* (18.9%). The most effective *Sr's* in the region were *Sr's Gt*$^{+}$ (51.5%), *7b* (42.3%), *5* (41.1%), *8a* (33.1%) and *30* (32.7%).

Spore Trapping

Burkard spore trap samplers were installed at seven sites in the region: Nubaria, Sids and Shandaweel in Egypt; Holetta, Debre Zeit and Kulumsa in Ethiopia; and New Halfa in Sudan (Fig. 1). The traps started to operate throughout the year in January 1993 in Ethiopia and starting in January 1994 at all the sites in Egypt and Sudan. All spore counting was stopped in early September 1997 to finalize the results of the study.

Due to factors out of control, mainly power cuts in remote areas, information from some trapping sites was missing. In these cases, the missing data were estimated as averages from preceding and following months.

Leaf Rust

Urediospores of wheat leaf rust were continually trapped from the air at Nubaria in the north of Egypt during all months from 1994 to 1997 (Appendix 3). More than 30 spores/m^3 of air were trapped in March, April and May, which happens to be the period during which the wheat crop flowers and matures in the region. However, the spores were also present during the non-cropping months of July, August, September and October and during the planting and seedling stages of the crop in November, December and January.

A relatively smaller number of spores than those trapped at Nubaria were trapped at Sids (15 to 23 spores/m^3 of air), although trapping large quantities of spores continued till June. Similarly, lesser quantities of spores were trapped towards the end of the cropping season (March to June) than during the off-season. There were no trapped spores in November and December 1994 and 1995, which were usually the months with very low counts in the other years. The fact that there was a zero count of spores in February 1994 and April 1995, the months during which the spore count normally increased with crop flowering in other years and locations, could not be explained. However, when the counts were averaged over the four years, every month had a spore count.

The number of spores trapped at Shandaweel in the south of Egypt followed a pattern similar to that at Sids (central Egypt) and Nubaria (northern Egypt). No spores were trapped in November and December 1994 and 1995 or in January 1995, 1996 and 1997. However, on the average of the four years, there was no month without trapped spores (Appendix 3).

Leaf rust spores were continually trapped at Holetta, central Ethiopia, every single month of the five years (Appendix 4). The count increased from 11 to 28 spores/m^3 of air in September through December, the time when the main-season wheat crop is generally after antithesis and at the grain-filling stage. Less than 2 spores/m^3 of air were trapped in 1993 and 1994, compared to about 20 spores/m^3 of air in 1995.

Relatively smaller numbers of spores were trapped in all months and years at Kulumsa, the most important bread-wheat producing region in southeastern Ethiopia. The spore count increased again with crop development in September, October and November. At least 1 spore/m^3 of air was trapped during the rest of the months.

Debre Zeit is located in the major durum-wheat producing region of central Ethiopia and has black clay soil (vertisol). After very low (sometimes zero) counts of leaf rust spores in 1993 and 1994, the count suddenly jumped to more than 200 spores/m^3 of air in some months of the following years. The planting of the main-season wheat crop in this vertisol region is usually slightly late, thus, the peaking of the spore count also started late in October and continued until December. There was another peak count in April (about 34 spores/m^3 of air), which was believed to originate from the off-season (irrigated) wheat crop planted at that location and maturing at that time. On the average of the five years, there were no months in which less than 5 spores/m^3 of air were trapped. Generally, the leaf rust spore counts at Debre Zeit were higher than those at other locations in Ethiopia or in the region (Fig. 6).

Spores were trapped for five years (1993–1997) at New Halfa, Sudan, and their numbers were generally low (less than 10 spores/m^3 of air) during the cropping season (Appendix 5). It was difficult to explain the absence of trapped spore in many months in 1993–1996, such as February, March and April of 1996, during which the crop usually matures and more spores are released. On the other hand, an unusually high count of spores in November and December 1996 could not have originated from the wheat crop, which had just been planted and was at the seedling stage at that time.

Stem Rust

Stem rust spore trapping generally followed the same trend as leaf rust spore trapping at all locations. There was no month in which stem rust spores were not trapped at Nubaria in the north of Egypt. The number of trapped spores increased with crop development in March, April and May (Appendix 6). November and December were with the least catch. As in leaf rust, stem rust spore trapping was lower in 1995 and 1996 than in 1994 and 1997. On the average, the proportion of leaf and stem rust spore counts was about the same.

At Sids in central Egypt, the stem rust spore count was zero in November and December 1994 and 1995 and in June and July 1996. A very large number of spores was counted in the first eight months of 1997. The number of spores trapped increased as the crop flowered and matured in February–May. It seems that stem rust spore counts start peaking earlier at that location than leaf rust. There seems to be no significant difference in the leaf and stem rust spore counts at that location.

At Shandaweel, stem rust spore counts started to increase in March, slightly later than at Sids but at a time similar to that at Nubaria. However, the peak counts were in March at Nubaria (51 spores/m^3 of air) and Sids (20 spores/m^3 of air) and in April at Shandaweel (20 spores/m^3 of air).

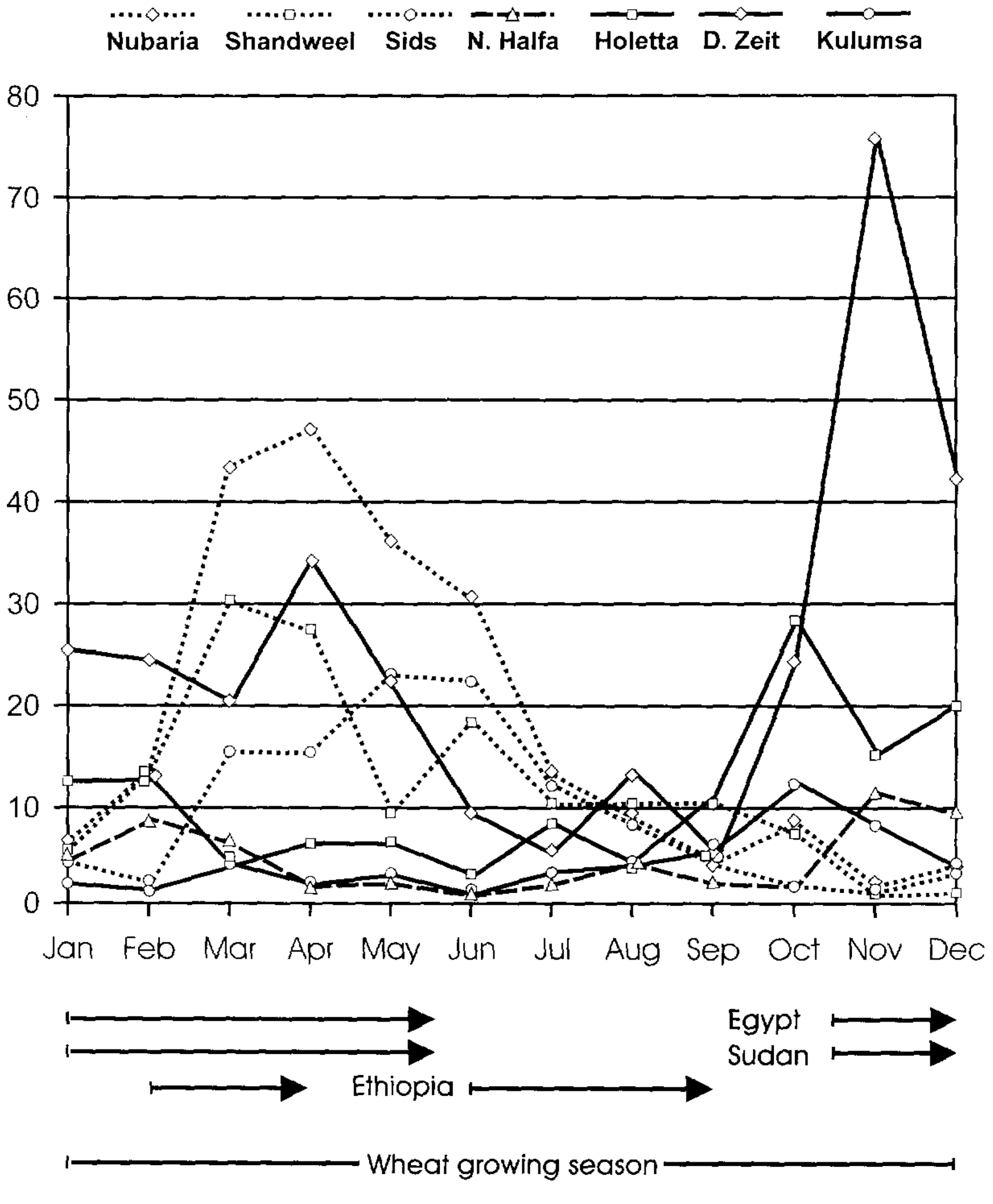


Fig. 6. Daily average number of leaf rust spores/m^3 of air at seven sites: three in Egypt (Nubaria, Shandaweel and Sids), three in Ethiopia (Holetta, Debre Zeit and Kulumsa), and one in Sudan (New Halfa).

Stem rust spores were continually trapped at Holetta, Ethiopia, every month (except March and June 1994) of the five years (Appendix 7). The average count over the years indicated that there were no months without a spore catch at that location. As in the case of leaf rust, the stem rust spore counts increased in October through December and peaked in October at that location. The spore counts increased (20 spores/m^3 of air) in 1995 and in later years after a low catch (less than 2 spores/m^3 air) in 1993 and 1994.

The stem rust spore count at Kulumsa was generally low, less than 10 spores/m^3 of air. Except for March and August 1993, and June and August 1994, at least 1 spore/m^3 of air was counted in all other months of the years. The number of spores increased in September through November, and peaked in October.

More stem rust spores were trapped at Debre Zeit than at any other location in the country or region (Appendix 7). On the average, up to 74 spores/m^3 of air were counted. Although there were many months in 1993 and 1994 with zero spore counts, nearly 300 spores/m^3 air were counted in April 1995 and November 1996. On average, over the years, the spore count ranged from 5 to 74 spores/m^3 of air. Generally, there were two peak counts, one in April and one in November. The first was due to a spore load from the off-season wheat crop planted at that location, and the second was from the main-season wheat crop which was maturing in November. Both leaf and stem rust spores were present in about the same proportion at Debre Zeit and followed very similar patterns. The peak spore count for both types of rust was in October at Holetta and Kulumsa. At Debre Zeit, it was one month later, in November, mainly due to the late planting practiced on the vertisol at that location (Figs. 6 and 7).

At New Halfa, Sudan, there were no stem rust spores trapped in August or September in all five years, except in August 1996 (Appendix 8). The spore count started to increase in November when the crop was being planted, and continued until April after peaking in March. The increase in November and December when the crop was at the seedling stage in Sudan could not be due to a local source.

Conclusion (Leaf Rust and Stem Rust)

The results of leaf and stem rust spore trapping from the air revealed that the spores of both rusts were present in the region throughout the year. In general, these spores were from local sources, mainly from the wheat crops grown in the respective locations. In Ethiopia, there are main-season and short-season wheat crops, and wheat crops planted at different times within the seasons depending on the rainfall and soil conditions of the location. Thus, urediospores of both rusts are continually released into the air, and the continuous trapping could be due to these local sources. However, the limited surveys made on a very small number of off-season wheat fields in the country showed that there was no rust infection of these crops, suggesting the possibility of the existence of other sources for the spores trapped during the off-seasons. On the other hand, the continuous spore catch during the non-cropping months in Egypt and Sudan suggests that spores trapped during that period were mainly from external sources. Therefore, it is the quantity and not the occurrence of spore load in the air during the different parts of the year that is more influenced by the cropping season and crop stage at all the locations in the region.

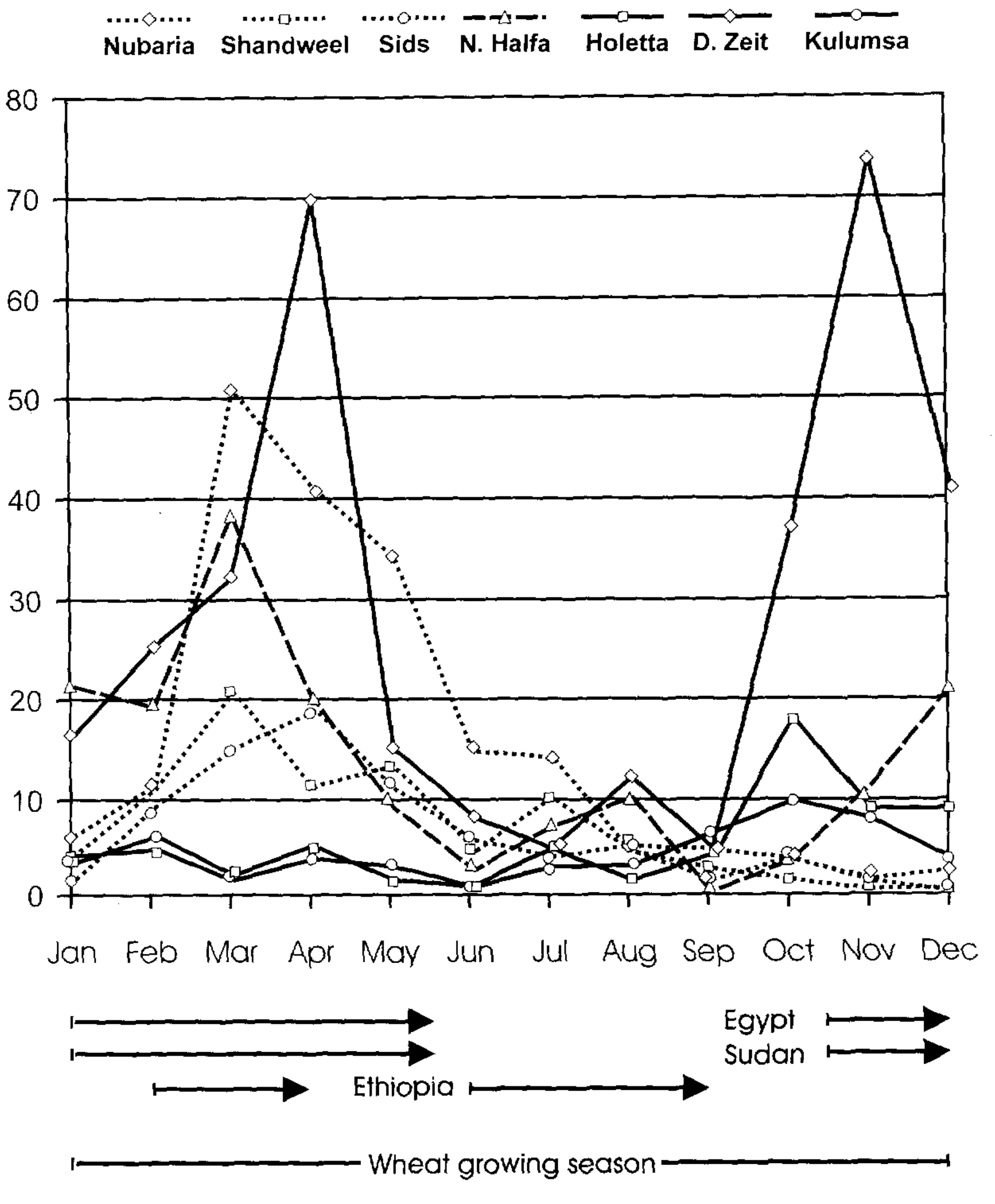


Fig. 7. Daily average number of stem rust spores/m^3 of air at seven sites: three in Egypt (Nubaria, Shandaweel and Sids), three in Ethiopia (Holetta, Debre Zeit and Kulumsa), and one in Sudan (New Halfa).

The wheat cropping season in the region could generally be divided into two parts: June to December in Ethiopia and November to June in Egypt and Sudan. Therefore, considering the region as a whole, there is no closed season for wheat growing. When the crop is maturing in November in Ethiopia (hence the spore load is at its peak), the crop is being planted in Egypt and Sudan. When the crop matures (and the spore load increases) in the latter countries in May and June, it is almost time to plant the main season crop in Ethiopia. It is therefore possible that the crop in Ethiopia becomes the source of inoculum for crops in Egypt and Sudan and vice versa, suggesting that there is an effective transport mechanism(s) (e.g., wind) for the spores to travel from one location to another within the region, with no physical barriers. Therefore, the spores remain biologically viable to initiate infection.

The peak spore load is in November in Ethiopia, February in Sudan and March in Egypt. Except for the two-month gap between November and February, this sequence could possibly suggest that the spores follow a northward movement and initiate infection following the cropping patterns.

Temperature and rainfall do not seem to have had an influence on the spore count in different years at all locations in Ethiopia. The lower rainfall might have influenced the low spore count in 1994. However, the spore count was also low in 1993, when the highest rainfall was recorded at all locations. It is important to note that larger numbers of spores of both rusts were counted at Debre Zeit, which has higher temperature and lower total rainfall than Holetta or Kulumsa.

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Appendix I. Severity† of leaf rust (*Puccinia recondita*) and type of infection of cultivars/lines in the Nile Valley and Red Sea Wheat Rusts Nursery (NVRSWRTN) at different planting sites, 1992/93–1996/97.

No.	Cultivar/Line *Lr* or *Sr* gene	Season	Egypt: Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	Sudan‡: New Halfa	CI	Ethiopia: Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Yemen: Dhamar	Seiyun	ACI
1	Thatcher^6 × Webster, *Lr 2a*	92/93	40 S	40 S	np	np	np	np	np	np	10 MR	10 S	10 S	10 S	19.0	20 S	16.0	np	0	np	20 S	0	tr MS	–	5.0	0	–	0
		93/94	40 S	40 S	np	60 S	60 S	60 S	np	np	np	40 S	tr S	0	37.8	0	0	0	np	0	30 S	10 S	np	np	10.0	–	0	0
		94/95	80 S	np	np	60 S	0	np	np	np	20 S	5 MR	0	10 R	23.3	70 MR-MS	28.0	0	np	0	np	10 MS	25 MS	np	7.0	0	5 MR	1
		95/96	np	20 MR-MS	5 S	20 MS	80 S	–	–	30 S	5 S	5 S	0	0	16.0	–	–	0	30 S	0	40 MS	0	5 MS	0	11.0	–	10 MS	8
		96/97	20 R	10 R-MR	0	0	0	5 S	0	0	tr S	20 S	20 S	10 S	6.0	5 MR	2.0	np	np	np	np	np	np	np	np	–	–	–
	Mean														20.4	–	11.5								6.8			1.8
2	Thatcher^6 × Hussar, *Lr 11*	92/93	40 S	40 S	np	np	np	np	np	np	10 MS	10 S	tr S	tr S	17.0	30 MR	12.0	–	5 R	np	30 S	0	10 MS		7.8	0	–	0
		93/94	40 S	50 S	np	60 S	60 S	60 S	np	np	np	60 S	tr S	tr S	42.2	0	0	0	np	0	0	0	np	np	0	–	0	0
		94/95	10 S	np	np	80 S	0	np	np	np	20 S	20 S	tr S	tr S	17.0	70 MS-S	6.0	0	np	0	np	0	10 MS	np	2.0	0	10 MR	2.0
		95/96	np	60 S	20 S	40 S	80 S	np	np	50 S	10 S	30 S	30 S	10 S	37.0	–	–	0	25 S	10 MS	10 MS	0	0	0	5.1	–	10 MS	80
		96/97	20 S	20 S	0	0	0	10 S	10 S	10 MS	tr S	60 S	40 S	10 S	12.0	5 R	1.0	np	np	np	np	np	np	np	np	–	–	–
	Mean														25.0	–	4.8								3.7			2.0
3	Thatcher^6 × Transfer, *Lr 9*	92/93	0	tr R	np	np	np	np	np	np	0	0	0	0	0.07	50 MR	20.0	np	30 S	np	np	0	5 S	10 MR	8.8	0		0
		93/94	10 MS-S	tr S	np	20 S	30 S	10 S	np	np	np	40 MR-MS	0	0	10.4	0	0	0	np	20 S	10 MS	0	np	np	7.0	–	0	0
		94/95	40 S	np	np	30 S	0	np	np	np	30 S	20 S	0	0	17.1	60 MS-S	48.0	0	np	0	np	0	40 MS	np	8.0	0	5 MS	20
		95/96	np	40 S	30 S	40 R	40 S	np	np	30 MS	0	10 R	0	0	4.7	–	–	0	30 S	20 S	40 MS	0	0	0	11.7	–	10 MS	80
		96/97	30 R	10 R	30 S	0	0	5 S	40 S	10 MS	tr S	20 R	20 S	tr S	9.7	10 MS	8.0	np	np	np	np	np	np	np	np	–	–	–
	Mean														8.4	–	19.0								8.9			2.0
4	Thatcher^6 × Klein Lucero, *Lr 17*	92/93	tr R	tr S	np	np	np	np	np	np	0	5 S	0	tr S	1.2	20 MR	8.0	np	0	np	40 S	0	15 MS	5 MR	10.5	0	–	0
		93/94	10 MS-S	40 S	np	10 S	10 MS-S	10 S		np	np	50 MR-MS	0	0	11.6	0	0	0	np	0	10 S	0	np	np	2.5	–	0	0
		94/95	50 S	np	np	20 MR	0	np	np	np	10 R	10 MR	np	0	11.0	50 MR-MS	20.0	0	np	0	np	0	30 MS	np	6.0	0	–	0
		95/96	np	40 R	0	40 R	0	np	np	30 MR	tr S	10 R	0	0	3.6		–	0	15 S	0	0	0	0	0	2.0	–	0	0
		96/97	40 R	10 R	0	0	0	10 S	0	0	tr R	0	40 S	10 S	5.9	10 MS	8.0	np	np	np	np	np	np	np	np	–	0	0
	Mean														67	–	9.0								5.3			0

† Severity = percent coverage with pustules.
‡ CI was used for Sudan since data were available from one site only.
tr = trace – 100; Infection type: R = resistant, MR = moderately resistant, MS = moderately susceptible, S – susceptible; ACI = average coefficient of infection; CI = coefficient of infection; np = not planted; – = reaction type not readable due to coverage of the leaf plant by other foliar diseases.

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
5	Thatcher[6] × Africa 43	92/93	0	tr MS	np	np	np	np	np	np	0	0	0	0	0.3	20 MS	8.0	–	–	np	60 S	0	0	–	20.0	0	-	0
		93/94	10 S	40 S	np	10 MS-S	10 MS-S	10 S	np	np	np	50 MS-S	tr MS-S	0	12.0	0	0	0	np	0	30 S	0	np	np	705	–	0	0
		94/95	tr S	np	np	20 S	10 S	np	np	np	10 S	10 R	0	0	6.3	6 R-MR	0.2	0	np	0	np	0	tr S	np	0.05	0	–	0
	Lr 18	95/96	np	60 R-MR	0	60 R	0	np	np	20 S	50 S	30 MS-S	0	0	13.1	–	–	0	15 S	0	20 MS	0	0	0	4.4	–	20 MS	16.0
		96/97	40 S	10 S	0	0	0	5 S	0	0	tr S	30 MS-S	5 S	tr S	7.3	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														7.8	–	2.1								18.6			3.2
6	Thatcher[6] × RL 5406	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0.0	5 MR	2.0	–	0	np	0	0	0	–	0	0	–	0
		93/94	30 S	30 S	np	30 S	30 S	40 S	np	np	np	40 S	5 S	5 S	26.3	5 MS-S	4.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	60 S	np	np	20 S	30 S	np	np	np	30 S	10 R	10 R	10 R	20.9	60 MR-MS	24.0	0	np	0	Np	0	20 MS	np	4.0	0	5 MR	2.0
	Lr 21	95/96	np	0	10 S	60 S	10 S	np	np	50 S	50 S	40 MR	5 S	5 S	16.7	–	–	0	10 S	0	10 MS	0	0	0	2.6	–	5 MS	4.0
		96/97	60 MR	0	0	0	0	5 S	0	0	0	30 MR	5 S	5 S	3.8	0	0	np	np	np	np	np	np	np	np	-	–	–
	Mean														13.5	–	7.5								1.7			1.2
7	Thatcher[6] × Lee 310	92/93	40 S	60 S	np	np	np	np	np	np	20 S	20 S	tr S	tr S	24.0	5 S	5.0	–	0	np	40 S	0	15 S	15 MS	11.1	0	–	0
		93/94	60 S	30 S	np	40 S	60 S	40 S	np	np	np	60 S	5 S	tr S	42.4	tr MR	0.8	0	np	50 S	30 S	0	np	np	20.0	–	0	0
		94/95	80 S	np	np	60 S	40 S	np	np	np	40 S	40 S	10 S	tr S	27.4	90 MR-MS	36.0	0	np	40 S	np	0	15 MS	np	13.0	0	20 MR	8.0
	Lr 23	95/96	np	80 S	0	tr MR	80 S	np	np	30 S	40 S	30 S	tr S	tr S	20.6		–	0	95 S	30 MS	40 MS	0	10 MS	0	7.4	–	50 MS	40.0
		96/97	60 S	40 S	40 S	0	5 S	40 S	60 S	10 S	20 S	60 S	tr S	tr S	28.3	0	0	np	np	np	np	np	np	np	np	-	-	-
	Mean														23.1		10.5								12.9			9.6
8	Agent	92/93	0	0	np	np	np	np	np	np	0	20 S	0	10 S	5.0	5 S	5.0	-	0	Np	60 S	0	10 MS	5 MS	12.0	0	–	0
		93/94	60 S	30 S	np	40 S	40 S	40 S	np	np	np	60 S	tr S	tr S	43.3	10 S	10.0	0	–	40 S	20 S	0	np	np	15.0	–	0	0
	Lr *26* and *Sr 24*	94/95	80 S	np	np	60 S	60 S	np	np	np	60 S	80 S	30 MS	30 MS	49.7	40 MS-S	32.0	0	–	40 S	np	0	tr MS	np	10.2	–	20 MR	8.0
		95/96	np	80 S	20 S	60 S	80 S	np	np	70 S	50 S	40 S	20 S	10 S	51.1	–	–	0	50 S	20 MS	40 S	0	20 S	0	18.0	–	40 MS	32.0
		96/97	40 S	40 S	50 S	0	0	40 S	60 S	50 S	5 S	70 S	tr S	0	59.8	10 MS	8.0	np	np	np	np	np	np	np	np	0	0	0
	Mean														35.8	–	13.8								13.8			8.0

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																									
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
	St. 1.25, Tc^h × *Lr 26*	92/93	0	tr MS-S	np	np	np	np	np	np	0	0	tr S	10 S	2.1	tr R	0.4	–	0	np	0	0	0	15 MS	2.0	0		0
		93/94	40 S	20 S	np	40 S	40 S	40 S	np	np	np	60 S	tr S	10 S	28.0	0	0	np	np	0	0	0	np	np	0	–	0	0
9		94/95	80 S	np	np	60 S	40 S	np	np	np	60 S	60 S	10 S	10 S	45.7	80 MS-S	64.0	0	np	0	np	0	30 MS	np	6.0	0	10 MR	4.0
	Lr 26 and *Sr 31*	95/96	np	80 S	50 S	60 S	80 S	np	np	30 S	40 S	60 S	10 S	10 S	46.7	–	–	0	25 S	0	40 S	0	0	0	2.6	–	0	0
		96/97	40 S	10 S	20 S	0	0	30 S	20 S	50 S	tr S	20 S	30 S	10 S	18.5	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														28.2	–	16.1								2.7			0.8
	Prelude × Reliance	92/93	10 S	10 S	np	np	np	np	np	np	tr MR-MS	30 S	tr S	tr S	8.7	5 MR	2.0	.	0	np	0	0	30 S	15 MS	7.0	0	-	0
		93/94	10 MS	10 S	np	10 S	10 MS-S	10 MS	np	np	np	10 MR-MS	0	tr S	8.0	20 S	20.0	0	np	10 S	10 S	0	np	np	5.0	–	0	0
10		94/95	40 MS	np	np	tr S	5 MR	np	np	np	tr S	20 R	tr S	tr S	5.1	40 MR-MS	16.0	0	np	10 S	np	0	30 MS	np	8.5	tr MR	–	0.8
	Sr 5	95/96	np	0	10 S	60 S	0	np	np	40 S	5 S	20 R	10 S	tr S	14.3	–	–	0	60 S	0	0	0	0	0	8.6		10 MR	4.0
		96/97	0	0	20 S	0	50 S	10 S	20 S	30 S	10 S	80 S	70 S	30 S	26.7	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														12.6		9.5								7.3			1.0
	Line Dsel	92/93	10 MS-S	20 S	np	np	np	np	np	np	10 S	0	0	10 S	8.0	tr MR	0.8		0	np	0	0	tr S	5 MR	0.7	0	–	0
		93/94	tr S	tr S	np	0	tr S	tr S	np	np	np	0	0	tr S	1.0	40 S	40.0	0	np	tr S	10 S	0	np	np	4.0	–	0	0
11		94/95	0	np	np	0	10 MR	np	np	np	tr R	10 R	0	tr S	0.9	30 MS-S	24.0	0	np	5 S	np	0	15 MS	np	4.3	0	10 MS	8.0
	Sr 6	95/96	np	20 S	20 S	tr R	20 S	np	np	50 S	tr S	10 R	0	0	1.6	–	–	0	80 S	0	10 S	0	30 S	0	17.1		0	0
		96/97	40 S	20 S	tr S	0	20 S	10 S	0	10 S	0	0	5 S	tr S	9.1	0		np	np	np	np	np	np	np	np	–	–	–
	Mean														–	–	–								6.5			1.6
	Vernstein	92/93	0	0	np	np	np	np	np	np	0	0	tr S	0	0.3	10 S	10.0	–	0	np	0	0	15 MS	-	2.3	0	.	0
		93/94	60 S	40 S	np	60 S	60 S	40 S	np	np	np	70 S	10 S	0	42.5	20 S	20.0	0	np	5 S	30 S	0	np	np	8.7	–	0	0
12		94/95	40 S	np	np	60 S	20 S	np	np	np	40 S	40 S	10 S	0	30.0	20 MR-MS	8.0	0	np	5 S	np	0	40 MS	np	9.3	–	10 MR	4.4
	Sr 9e	95/96	np	70 S	40 S	0	60 S	np	np	80 S	20 S	40 S	30 S	10 S	38.9	–	–	0	95 S	0	60 S	0	20 S	0	25.0	50 S	20 MR	29.0
		96/97	60 S	30 S	0	0	0	5 S	5 S	10 S	10 S	40 S	80 S	30 S	22.5	0	–	np	np	np	np	np	np	np	np	.		-

Appendix 1. (Cont'd)

No.	Cultivar/ Line / *Lr* or *Sr* gene	Season	Egypt: Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	Sudan‡: New Halfa	CI	Ethiopia: Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Yemen: Dhamar	Seiyun	ACI
13	Line AG	92/93	20 S	20 S	np	np	np	np	np	np	10 S	0	tr S	tr S	8.9	tr MS-S	1.6	–	0	np	0	0	0	tr MR	0.1	0	–	0
		93/94	10 S	tr S	np	20 S	10 S	30 S	np	np	np	5 S	0	tr S	9.9	30 S	30.0	0	np	0	tr S	0	np	np	0.5	–	0	0
		94/95	40 MR	np	np	0	tr S	np	np	np	tr R	0	0	0	2.0	20 MS-S	16.0	0	np	0	np	0	tr MS	np	0.4	tr MS	0	1.6
	Sr 11	95/96	np	80 S	40 S	60 S	0	np	np	30 MR-MS	tr R	0	0	0	21.3	–	–	5 MS	50 S	0	0	tr MS	tr R	0	8.0		5 MR	2.0
		96/97	0	0	0	0	0	0	0	0	5 S	0	5 S	5 S	1.3	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														8.7	–	11.9								2.3			
14	Einkorn	92/93	0	10 S	np	np	np	np	np	np	0	0	0	0	1.7	10 S	10.0	–	0	np	40 S	0	0	tr MR	6.8	0	–	0
		93/94	10 S	40 S	np	10 S	10 S	10 S	np	np	np	40 MS-S	10 S	0	15.3	10 S	10.0	0	np	5 S	0	0	np	np	1.2	–	0	0
		94/95	10 S	np	np	0	0	np	np	np	tr S	40 S	10 S	0	8.9	30 MS	24.0	0	np	5 S	np	0	5 MS	np	2.3	0	0	0
	Sr 21	95/96	np	10 MS-S	60 S	0	0	np	np	40 S	0	40 S	10 S	0	17.7	–	–	0	80 S	0	0	0	5 MS	0	12.0	0	10 MR	2.0
		96/97	0	0	5 S	0	0	50 S	0	10 S	40 S	0	10 S	5 S	6.3	0	0	np	np	np	np	np	np	np	np	..	..	.
	Mean														10.0	–	11.0								5.3			0.4
15	LC *Sr 25* Ars	92/93	10 S	40 S	np	np	np	np	np	np	10 S	0	tr S	tr S	10.7	5 MR	2.0	–	0	np	40 S	0	0	10 MR	7.3	0	0	0
		93/94	60 S	60 S	np	10 S	10 S	10 S	np	np	np	60 S	10 S	tr S	27.8	40 S	40.0	0	np	10 S	30 S	0	np	np	10.0	0	0	0
		94/95	40 S	np	np	0	0	np	np	np	10 S	60 S	10 S	0	17.1	20 MR-MS	8.0	0	np	10 S	np	0	10 MS	np	7.3	–	–	–
	Sr 25	95/96	np	40 R	40 S	20 R-MR	0	np	np	60 S	60 S	40 S	tr S	tr S	28.0	–	0	0	20 S	10 MS	60 S	0	20 MS	0	14.9	–	20 MR	8.0
		96/97	50 R	10 R	5 MS	0	0	5 S	0	5 S	5 S	0	tr S	0	2.8	0	0	np	np	np	np	np	np	np	np	..	40 MS	32.0
	Mean														–	–	–								9.9			8.0
16	Eagle	92/93	0	0	np	np	np	np	np	np	0	tr S	tr S	0	0.7	10 S	10.0	.	10 S	np	0	0	15 S	tr MR	4.2	0	–	0
		93/94	60 S	60 S	np	30 S	60 S	60 S	np	np	np	70 S	10 S	0	43.8	70 S	70.0	0	np	0	10 S	0	np	np	2.5	–	0	0
		94/95	80 S	np	np	20 S	20 S	np	np	np	30 S	80 S	tr S	0	29.0	40 MS-S	32.0	0	np	0	np	0	30 MS	np	6.0	–	5 MS	3.0
	Sr 2 and *Sr 26*	95/96	np	30 S	20 S	40 S	80 S	np	np	80 S	10 S	40 S	tr S	0	33.6	–	–	0	85 S	0	20 S	0	20 MS	0	17.3	.	60 S	60.0
		96/97	40 S	30 S	10 S	0	0	5 S	40 S	20 S	40 S	30 S	tr S	0	27.3	0		np	np	np	np	np	np	np	np	–	–	–
	Mean														26.9	–	28.0								7.5			12.6

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
17	W2691	92/93	20 S	40 S	np	np	np	np	np	np	10 S	0	0	tr S	13.7	tr S	2.0		10 S	np	0	0	20 MS	5 MR	4.7	0	-	0
		93/94	60 S	70 S	np	60 S	60 S	60 S	np	np	np	60 S	10 S	tr S	40.3	20 S	20.0	np	np	np	np	np	np	np	np		0	0
	Sr 28 Kt	94/95	60 S	np	np	40 S	10 S	np	np	np	30 S	40 S	10 S	10 S	28.6	10 MR	4.0	0	np	5 S	np	0	25 MS	np	6.3	-	60 S	60.0
	Sr 27	95/96	np	50 S	70 S	20 MS	100 S	np	np	80 S	40 S	40 S	10 S	10 S	55.8	-		0	10 S	10 MS	tr R	0	0	0	2.6	-	60 S	60.0
		96/97	60 S	30 S	0	0	0	5 S	10 S	10 S	10 S	80 S	10 S	10 S	18.8	tr R	0.4	np	np	np	np	np	np	np	np		-	-
	Mean														31.3	-	6.6								4.5			24.0
18	Gamut	92/93	0	tr MR-MS	np	np	np	np	np	np	tr S	0	0	0	0.4	10 S	10.0	-	0	np	20 S	0	5 MS	tr MR	4.0	0	-	0
		93/94	60 S	40 S	np	60 S	60 S	60 S	np	np	np	60 S	5 S	0	43.1	20 S	20.0	0	np	0	10 S	0	np	np	2.5		0	0
		94/95	60 S	np	np	20 S	5 S	np	np	np	20 S	40 S	0	0	20.7	40 S	40.0	0	np	0	np	0	10 MS	np	2.0	-	10 MR	4.0
	Sr Gt	95/96	np	30 S	0	80 S	50 S	np	np	40 S	30 S	40 S	0	0	28.9	-		0	85 S	0	20 MS	0	10 MS	0	15.6	50 S	5 MR	26.0
		96/97	0	0	0	0	0	10 S	10 S	5 S	20 S	20 S	0	0	5.4	0	0	np	np	np	np	np	np	np	np	-	-	-
	Mean														-	-	17.5								6.0			6.0
19	*Triticum timopheevii*	92/93		-	np	-		np	np	np			-	-	-	np		np	np	np	np	np	np	np	np	np	np	-
		93/94	20 S	50 S	np	30 S	10 S	0	np	np	np	60 S	tr S	0	21.5	10 MR-MS	4.0	np	np	20 S	30 S	0	np	np	12.5		tr R	0.4
		94/95	20 S	np	np	40 S	60 S	np	np	np	10 S	0	5 S	0	19.3	50 S	50.0	0	0	np	0	40 MS	np	np	8.0	0	60 S	30.0
	Sr Tt-1 (36)	95/96	np	30 S	70 S	80 S	80 S	np	np	0	70 S	10 S	0	0	37.8	-	-	0	80 S	40 MS	40 S	0	np	np	30.0	-	80 S	80.0
		96/97	0	0	tr S	0	0	5 S	40 S	0	0	0	0	0	3.9	0	0	np	np	np	np	np	np	np	np	-	-	-
	Mean														16.5	-	13.5								16.8			7.7
20	Giza 155	92/93	10 S	20 S	np	np	np	np	np	np	0	0	0	0	5.0	5 S	5.0	10 S	20 S	np	60 S	0	20 MS	5 MR	18.3	40 S	tr R	20.2
		93/94	60 S	40 S	np	60 S	10 S	40 S	np	np	np	60 S	tr S	0	34.0	20 S	20.0	30 S	np	10 S	10 S	0	np	np	12.5	10 S	tr R	5.2
		94/95	10 S	np	np	20 MS-S	80 S	np	np	np	10 S	60 S	0	0	22.0	40 S	40.0	np	0	0	np	0	5 MS	0	1.0	10 S	20 MR	9.0
		95/96	np	40 S	10 S	40 S	80 S	np	np	60 S	80 S	10 S	10 S	0	36.7	-	-	0	5 MS	10 MS	40 S	0	40 S	0	18.3	60 S	5 MR	31.0
		96/97	60 S	10 S	0	5 S	0	5 S	20 S	5 S	10 S	0	0	0	9.6	0	0	np	np	np	np	np	np	np	np		-	-
	Mean														21.5	-	16.3								12.5			13.1

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													*Sudan*‡		*Ethiopia*								*Yemen*		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
21	Giza 157	92/93	0	0	np	0	np	np	np	np	0	0	0	0	0	tr MS	1.6	np	0	np	10 MR	np	np	np	2.0	tr R	tr R	0.2
		93/94	10 S	10 S	np	20 S	10 S	10 S	np	np	np	20 MS-S	0	0	9.5	0	0	0	np	np	0	0	0	np	0	–	tr R	0.4
		94/95	5 S	np	np	20 S	np	np	np	np	5 S	80 S	0	0	13.8	10 MS	8.0	np	np	np	np	np	np	np	0	5 MS	tr R	0.6
		95/96	np	0	0	20 S	0	np	np	20 S	0	0	0	0	4.4	–	–	0	10 S	0	0	0	0	–	0.7	0	5 MS	1.0
		96/97	60 S	40 S	0	0	0	20 S	20 S	5 MR	10 S	0	40 S	10 S	16.8	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														8.9	–	2.4								0.7			0.4
22	Giza 162	92/93	0	0	0	np	np	np	np	np	0	0	0	0	0	tr MR-MS	0.8	–	0	np	0	0	0	15 MS	2.0	0	–	0
		93/94	10 S	10 S	np	10 S	10 S	60 S	np	np	np	10 MS-S	0	0	13.5	20 S	20.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	20 MS	np	np	5 S	0	np	np	np	0	0	0	–	3.0	5 MS	4.0	0	np	5 S	np	0	0	np	1.2	–	5 MR	2.0
		95/96	np	0	0	60 S	0	np	np	0	0	0	0	0	6.7	–	–	0	10 MS	0	0	0	0	0	1.1	–		
		96/97	80 S	40 S	20 S	0	0	5 S	5 S	5 S	0	0	5 S	0	14.2	0	0	np	np	np	np	np	np	np	np		–	–
	Mean														7.5	–	6.2								1.2			0.4
23	Giza 163	92/93	0	0	np	np	np	np	np	np	0	0	tr S	0	0.1	0	0	–	0	np	20 S	0	0	–	3.3	0	–	0
		93/94	40 S	tr S	np	10 S	40 S	60 S	np	np	np	60 MS-S	0	0	25.0	30 S	30.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	40 S	np	np	10 S	5 S	np	np	np	10 S	80 S	10 S	0	22.1	40 S	40.0	0	np	0	np	0	0	np	0	–	5 MR	2.0
		95/96	np	20 S	0	0	60 S	np	np	60 S	0	10 S	10 S	10 S	18.9	–		0	10 MS	0	0	0	0	0	1.1	20 S	0	10.0
		96/97	20 S	10 S	0	0	0	5 S	5 S	5 S	tr S	10 MS	40 S	10 S	11.7	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														15.6		17.5								1.1			2.4
24	Giza 164	92/93	0	0	np	np	np	np	np	np	0	0	tr S	0	0.1	tr MS-S	2.0	–	0	np	0	0	0		0	0	–	0
		93/94	60 S	tr S	np	40 S	60 S	60 S	np	np	np	60 MS-S	0	0	33.8	30 S	30.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	tr S	np	np	10 S	0	np	np	np	tr S	20 S	0	0	4.9	tr MR	0.8	0	np	0	np	0	0	np	0	0	0	0
		95/96	np	10 S	0	60 S	0	np	np	5 S	tr S	10 S	10 S	0	8.8	–	–	np	30 S	0	0	0	0	0	4.3		5 MR	2.0
		96/97	40 S	40 S	0	0	0	5 S	0	0	0	0	5 S	0	7.5	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														11.0		8.2								1.1			0.4

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
25	Giza 165	92/93	0	0	np	np	np	np	np	np	0	0	tr S	0	0.1	0	0	–	0	np	0	0	0	–	0	0	–	0
		93/94	20 S	tr S	np	30 S	10 S	10 S	np	np	np	10 MS-S	tr S	0	10.3	30 S	30.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	5 S	np	np	10 S	20 S	np	np	np	10 S	40 MR	0	0	7.8	5 R-MR	1.0	0	np	0	np	0	0	np	0	0		0
		95/96	np	10 S	0	0	40 S	np	np	40 S	0	10 R	0	0	16.2	–		0	5 MR	0	0	0	0	0	0.3	–	20 MR	8.0
		96/97	40 S	20 S	0	0	0	10 S	5 S	0	tr S	40 MS	10 S	0	9.8	tr R	0.2	0	5 MR	0	0	0	0	0	0.3	–	20 MR	8.0
	Mean														8.9	–	7.8								0.2			3.2
26	Sakha 8	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2.0		0	np	0	0	0	np	0	0	–	0
		93/94	30 MS-S	tr S	np	30 S	30 MS-S	30 S	np	np	np	30 MS	0	0	16.8	20 S	20.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	10 S	np	np	20 S	tr S	np	np	np	tr S	0	0	0	4.9	5 R-MR	1.0	0	np	0	np	0	0	np	0	10 MS	·	8.0
		95/96	np	5 S	0	10 MR	0	np	np	0	0	0	0	0	0.6	–	–	0	20 S	0	0	0	0	0	2.9	–	10 MR	4.0
		96/97	0	0	0	0	0	5 S	0	tr S	30 S	0	0	0	3.1	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														5.1	–	5.8								0.7			2.4
27	Sakha 69	92/93	0	0	np	np	np	np	np	np	0	0	tr S	0	0.3	tr MS-S	2.0		0	np	30 S	0	0	np	5.0	0	–	0
		93/94	10 S	40 S	np	20 S	60 S	0	np	np	np	20 MR-MS	0	0	17.3	20 S	20.0	0	np	0	10 S	0	np	np	2.5	–	0	0
		94/95	10 MS	np	np	20 S	0	np	np	np	0	0	0	0	4.0	5 R-MR	1.0	0	np	0	np	0	N	np	0	·	10 MR	4.0
		95/96	np	0	0	10 R	0	np	np	10 MR	0	0	0	0	0.7			0	30 S	0	0	0	0	0	4.3	–	40 MS	32.0
		96/97	0	0	0	10 S	0	10 S		0	10 S	0	0	0	2.5	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														5.0	·	5.8								3.0			7.2
28	Sakha 92	92/93	20 S	30 S	np	np	np	np	np	np	np	0	tr S	tr S	9.0	tr-5R	2.0	–	0	np	0	0	0	np	0	0	–	0
		93/94	60 S	30 S	np	50 S	60 S	0	np	np	0	20 MS-S	0	10 MS-S	28.0	5 S	5.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	60 S	np	np	0	5 S	np	np	np	10 S	40 S	0	tr S	16.0	5 S	5.0	0	np	0	np	0	N	np	0	–	0	0
		95/96	np	0	0	tr MR	30 S	np	np	40 S	0	20 S	10 S	10 S	12.2	–	–	0	15 S	0	0	0	0	0	2.1	–	5 MR	2.0
		96/97	40 R	30 R	0	0	0	5 S	0	0	0	0	5 S	0	3.7	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														13.8	–	4.0								0.5			0.4

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
29	Gemmeiza 1	92/93	0	0	np	np	np	np	np	np	0	0	tr S	tr S	0.7	Tr R	2.0	–	0	np	80 S	0	0	np	13.30	0	-	0
		93/94	tr S	tr S	np	10 S	10 S	0	np	np	np	50 S	tr S	20 MS-S	10.9	10 MS	8.0	0	np	0	30 S	0	np	np	7.5	–	0	0
		94/95	10 MS	np	np	10 S	10 S	np	np	np	10 S	10 MS	tr S	20 MR-MS	7.7	10 R	2.0	0	np	0	np	0	tr MS	np	0.1	–	20 MR	16.0
		95/96	np	0	30 S	60 S	60 S	np	np	60 S	10 S	10 S	10 S	10 S	27.8	–	–	0	60 S	0	100 S	0	0	0	22.9		5 MR	2.0
		96/97	0	0	5 S	0	0	0	5 S	10 S	40 S	0	30 S	0	7.5	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														10.9	–	3.0								10.9			3.6
30	*Triticum spelta saharense*	92/93	80 S	70 S	np	np	np	np	np	np	40 S	70 S	50 S	30 S	56.7	20 S	20.0	–	0	10 S	0	0	40 S	np	8.3	5 S	70 S	35.0
		93/94	70 S	80 S	np	80 S	80 S	60 S	np	np	np	70 S	10 S	10 S	57.5	30 S	30.0	90 S	np	30 S	10 S	10 S	np	np	48.0	40 S	10 S	25.0
		94/95	90 S	np	np	90 S	80 S	np	np	np	70 S	90 MS	10 S	5 MR-MS	55.0	40 S	40.0	0	50 S	40 S	10 S	0	50 S	np	37.5	40 S	90 S	65.0
		95/96	np	80 S	60 S	100 S	100 S	np	np	80 S	80 S	40 S	30 S	20 S	65.6	–	–	0	100 S	50 S	0	0	20 S	10 MS	25.4	40 S	40 S	40.0
		96/97	80 S	60 S	10 S	50 S	60 S	40 S	40 S	40 S	70 S	100 S	80 S	40 S	52.5	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														57.5	–	22.5								29.8			33.0
31	Beni Suef 1	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr MS	1.6	40 S	0	np	0	0	0	-	6.7	0	–	0
		93/94	tr R	20 S	np	tr R	0	0	np	np	np	30 MS-S	0	0	5.6	20 S	20.0	0	np	0	0	0	np	np	0	–	3 MS	0.8
		94/95	0	np	np	tr MR-MS	0	np	np	np	0	0	0	0	0.03	10 MR-MS	4.0	0	np	0	np	tr MS	tr MS	np	0.8	–	40 MR	16.0
		95/96	np	30 MS-S	0	tr R	5 S	np	np	40 S	10 MS	10 S	0	0	9.7	–	–	0	100 S	30 S	0	0	tr MS	0	32.9	–	40 MS	32.0
		96/97	5 R	tr R	0	0	0	5 MR	0	5 MR	0	40 S	5 S	0	4.02	0	0	np	np	np	np	np	np	np	np			
	Mean														3.9	–	6.4								10.1			9.8
32	Sohag 1	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	5 S	5.0	40 S	0	np	0	0	20 MS	–	9.3	0	–	0
		93/94	tr S	10 S	np	10 MS-S	5 S	0	np	np	np	60 S	0	0	10.6	10 MR-MS	4.0	10 S	np	0	10 S	10 S	np	np	7.5	–	0	0
		94/95	tr S	np	np	30 MS	5 S	np	np	np	tr S	10 MR	10 R	0	5.6	5 R-MR	1.0	0	np	0	np	20 S	tr MS	0	5.4	40 S	0	20.0
		95/96	np	60 S	0	20 MS-S	30 S	np	np	60 S	0	10 R	0	0	18.7	–	–	10 MS	50 S	30 MS	0	np	30 MS	np	15.1	60 S	5 MR	31.0
		96/97	20 S	10 S	tr S	0	0	5 S	tr S	tr S	tr MS	10 S	10 S	10 S	5.9	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														8.2	–	2.5								9.3			10.2

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
33	Sohag 2	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2.0	60 S	5 MR	Np	0	0	40 S	5 MR	17.3	0		0
		93/94	10 S	30 S	np	10 MS-S	10 S	0	np	np	np	40 MS-S	0	0	11.3	10 MS-S	8.0	0	np	0	0	30 S	np	np	7.5	-	0	0
		94/95	tr S	np	np	40 MR-MS	0	np	np	np	tr S	0	0	0	2.8	tr MR	0.8	5 MS	np	0	np	20 S	10 MS	np	6.4	30 S	0	15.0
		95/96	np	50 S	0	10 MS-S	20 S	np	np	40 S	0	30 MS	0	0	15.8	-	-	10 MS	25 S	20 MR	0	10 MS	0	0	6.4	80 S	5 MR	41.0
		96/97	10 R	10 R	0	0	0	0	tr S	0	tr S	70 MS	60 S	10 S	11.2	0	0	np	np	np	np	np	np	np	np	-	-	
	Mean														8.2	-	2.7								9.8			11.2
34	Sohag 3	92/93	10 MR-MS	5 MR-MS	np	np	np	np	np	np	10 MS-S	0	0	0	1.8	tr S	2.0	50 S	5 MR	np	0	0	40 S	5 MR	15.7	0	-	0
		93/94	0	10 S	np	tr R	10 S	0	np	np	np	60 S	0	0	10.0	50 S	50.0	0	np	0	0	10 S	np	np	2.5	-		0
		94/95	0	np	np	50 S	0	np	np	np	10 S	10 MS	10 MS	0	10.9	30 MS	24.0	0	10 MR	0	np	40 S	20 MS	np	15.0	5 S	80 S	42.0
		95/96	np	40 S	0	20 MS-S	60 S	np	np	60 S	0	10 MS	10 MS	0	21.3	-	-	30 MS	30 S	30 MS	0	0	40 MS	0	13.4	60 S	40 S	50.0
		96/97	40 MS	10 R	0	10 R	40 S	0	5 MS	20 MS-S	5 R	10 S	5 S	10 S	10.2	0	0	np	np	np	np	np	np	np	np	-	-	
	Mean														10.8	-	19.0								11.7			18.4
35	Gemmeiza 3	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	30 R	5 MR	np	0	30 MS-S	10 S	tr MR	11.1	0	-	0
		93/94	tr R	40 S	np	tr R	tr S	0	Np	np	np	5 MR-MS	0	0	5.6	10 MR-MS	4.0	0	np	0	tr MS	0	np	np	0.1	-	0	0
		94/95	0	np	np	10 S	40 S	np	np	np	0	20 MS	0	0	9.4	10 R-MR	2.0	0	tr MS	0	np	5 MS	20 MS	Np	5.4	-	-	-
		95/96	np	0	0	0	0	np	np	30 S	30 S	10 MS	10 MS	0	8.2		-	0	30 S	10 MR	40 S	0	0	0	10.6	-	5 MR	2.0
		96/97	10 S	10 S	0	0	0	5 S	10 S	5 S	0	0	0	0	3.3	0	0	np	np	np	np	np	np	np	np	-		-
	Mean														5.3	-	1.5								19.3			0.4
36	Giza 160	92/93	60 S	70 S	np	np	np	np	np	np	40 S	30 S	10 S	10 S	36.7	np	-	np	0	0	0	0	5 MS	np	0.7	tr R	tr R	0.2
		93/94	60 S	80 S	np	60 S	60 S	60 S	np	np	np	80 S	10 S	10 S	52.5	30 S	30.0	10 S	np	60 S	40 S	40 S	np	np	37.5	tr R	5 MR	0.3
		94/95	60 S	np	np	80 S	50 S	np	np	80 S	80 S	40 S	10 S	10 S	58.6	20 MR-MS	8.0	10 S	np	30 S	30 S	10 S	5 MS	np	21.0	10 S	50 MR-MS	15.0
		95/96	np	90 S	70 S	40 S	80 S	np	np	80 S	80 S	70 S	40 S	20 S	67.8	-	-	10 S	5 S	0	0	0	0	10 S	3.6	10 S	10 S	10.0
		96/97	40 S	30 S	5 S	0	0	0	10 S	10 S	10 S	60 S	0	0	13.8	0	0	np	np	np	np	np	np	np	np	-	-	-
	Mean														45.9	-	12.7								15.7			5.1

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
37	Enkoy	92/93	10 S	tr S	np	np	np	np	np	np	0	0	0	0	1.9	tr MS-S	1.6	–	0	np	30 S	0	25 S	tr MR	9.3	0	–	0
		93/94	60 S	20 S	np	40 S	10 S	0	np	np	np	10 MR-MS	0	0	17.3	5 R-MR	1.0	0	np	30 S	30 S	0	np	np	15.0	–	0	0
		94/95	80 S	np	np	20 S	30 S	np	np	np	20 S	10 S	0	0	22.9	0	0	0	np	40 S	np	0	25 MS	np	15.0	–	0	0
		95/96	np	0	0	20 R	0	np	np	0	tr S	10 S	0	10 S	2.9	..	–	0	5 R	0	20 S	0	0	0	3.0	–	0	0
		96/97	30 R	0	0	0	0	0	0	5 MS	0	40 S	tr MS	0	4.3	0	0	np	np	np	np	np	np	np	np		–	–
	Mean														9.9		0.5								10.6			0.0
38	K 6890-B	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	–	0	np	0	0	0	–	0	0	–	0
		93/94	10 S	10 S	np	20 S	10 S	0	np	np	np	20 MR-MS	0	0	7.3	0	0	0	np	0	0	0	np	np	0		0	0
		94/95	5 S	np	np	30 S	0	np	np	np	10 S	0	0	0	6.4	tr MR-MS	0.8	0	np	5 S	np	0	0	np	0.8	0	–	0
		95/96	np	10 S	0	20 MS-S	0	np	np	50 S	0	0	0	0	8.4	–		0	80 S	0	–	0	20 MS	0	13.7	10 S	0	5.0
		96/97	20 S	10 S	0	0	5 S	0	tr S	tr MR-MS	0	0	20 S	tr S	5.0	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														5.4	–	0.3								3.6			1.0
39	Dashen	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr R	0.4	–	0	np	10 S	0	25 S	tr MS	6.0	0	–	0
		93/94	0	0	np	0	tr S	0	np	np	np	20 MR MS	0	0	1.3	0	–	0	np	0	0	0	np	np	0	–	0	0
		94/95	0	np	np	20 S	5 S	np	np	np	5 S	0	0	0	1.7	5 R-MR	1.0	0	np	5 S	np	0	0	np	1.2	0	0	0
		95/96	np	0	tr MS	40 S	0	np	np	30 S	tr MS	0	0	0	8.1	–	–	0	5 MR	0	60 S	0	0	0	9.1	–	5 MR	0.4
		96/97	10 R	tr R	0	0	0	5 S	5 S	5 MS	tr M	20 MS	5 S	0	3.1	0	0	np	np	np	np	np	np	np	np	–		–
	Mean														2.8	–	0.4								4.1			0.1
40	ET-13	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	–	0	np	5 MS	0	tr MS	–	0.8	0	–	0
		93/94	30 S	40 S	np	40 S	10 S	0	np	np	np	40 S	0	0	20.0	10 MR-MS	4.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	20 S	np	np	10 MR	10 MR	np	np	np	10 R	0	0	0	6.0	tr MR	0.8	0	np	0	np	0	0	np	0	0	0	0
		95/96	np	10 S	0	60 R	0	np	np	80 S	tr S	10 S	tr S	tr S	13.1	–	–	0	70 S	0	0	10 MS	5 MS	0	11.7	40 S	10 MS	24.0
		96/97	40 R-MR	0	0	0	20 S	0	5 S	tr MR-MS	5 MS	0	30 S	tr S	5.7	0	0	np	np	np	np	np	np	np	np	..	–	–
	Mean														9.0	–	1.2								3.1			4.8

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
41	K 6295-4A	92/93	0	0	np	np	np	np	np	np	np	0	0	0	0	0	0	–	0	np	0	0	0		0	0	–	0
		93/94	10 S	tr S	np	20 S	10 S	0	np	np	0	50 MS-S	0	0	10.3	0	0	0	np	0	0	0	np	np	0	–	0	0
		94/95	10 S	np	np	10 MS-S	0	np	np	np	0	0	0	0	2.3	10 MR-MS	4.0	0	np	0	np	0	0	np	0	0	0	0
		95/96	np	30 S	0	40 MR	5 S	np	np	30 S	tr S	20 MS	5 S	0	11.6			0	70 S	0	20 MS	0	25 MS	0	15.0	10 MR	0	0.2
		96/97	60 MS-S	10 S	0	10 S	0	40 S	0	0	tr S	0	0	0	9.2	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														6.7		1.0								3.8			0.1
42	C.T. 71/CII	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0		5 MR	np	20 S	0	tr MS	5 MR	3.9	0	–	0
		93/94	10 S	0	np	10 S	tr S	0	np	np	np	20 MS-S	0	0	4.8	0	0	0	np	0	10 S	30 S	np	np	3.9	–	0	0
		94/95	5 S	np	np	0	tr S	np	np	np	tr S	0	0	0	1.1	10 R-MR	2.0	0	5 MS	5 S	np	20 MS	20 MS	np	10.3	–	0	0
		95/96	np	tr MS	0	10 MR	0	np	np	10 S	tr S	0	10 MR	tr S	2.6		·	0	10 MS	10 S	20 MS	0	tr MS	0	5.1	–	5 MR	2.0
		96/97	40 R	30 S	5 S	60 R	0	5 MR-MS	0	tr MS	tr S	0	10 S	10 S	6.9	0	0	np	np	np	np	np	np	np	np	·	–	–
	Mean														5.1		0.5								7.3			0.4
43	Bohai	92/93	0	0	np	10 S	tr S	0	np	np	0	0	0	0	2.0	Tr R	2.0	·	0	np	0	0	0	tr MR	0.1	0	-	0
		93/94	tr S	0	np	20 MR	0	np	np	np	tr S	0	0	0	1.5	5 MS	1.0	0	np	0	10 MS	10 MS	np	np	4.0	·	0	0
		94/95	0	10 S	np	10 MR	30 MS-S	np	np	np	tr S	50 S	0	0	11.0	20 R-MR	4.0	0	10 MS	0	np	30 MS	30 MS	np	0.6	0	0	0
		95/96	np	60 MS	10 S	10 S	0	40 S	np	0	tr S	0	0	0	11.3	-	-	10 MR	20 S	10 MS	60 S	0	20 MS	5 MS	16.0	10 MR	5 MR	2.5
		96/97	40 MS	10 MS	40 R	tr S	0	0	10 S	5 S	40 S	20 MS	10 S	10 S	11.7	0	0	np	np	np	np	np	np	np	np	·		·
	Mean														11.1	-	1.8								8.0			0.5
44	Cocorit 71	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2.0	–	10 R	np	10 MR	0	tr MR	15 MR	2.0	0	–	0
		93/94	tr S	0	np	10 S	tr S	0	np	np	np	50 S	0	0	8.0	30 MR-MS	12.0	0	np	40 MS	20 MS	30 S	np	np	19.5	–	0	0
		94/95	tr S	np	np	20 MR-MS	0	np	np	np	tr S	0	0	0	0.7	30 R-MS	12.0	0	5 R	np	np	0	25 MS	np	5.3	0	0	0
		95/96	np	20 S	5 S	40 MR	5 S	np	np	60 S	0	10 S	tr S	tr S	13.3	–	–	20 MS	80 S	40 MS	0	30 S	20 MS	20 MS	27.1	0	10 MS	4.0
		96/97	60 R	30 R	0	5 R	40 S	0	40 R	0	0	0	40 S	10 S	9.8	0	0	np	np	np	np	np	np	np	np	–	–	-
	Mean														6.4	–	6.5								13.5			0.1

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
45	DZ 04-118	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	5 R	1.0	–	10 R	np	40 S	5 MS	50 S	40 MS	21.3	np	np	np
		93/94	10 S	30 S	np	10 S	tr S	0	np	np	np	60 S	0	0	14.0	0	0	0	np	30 S	40 S	40 S	np	np	30.0	0	–	0
		94/95	20 S	np	np	60 S	0	np	np	np	10 S	10 S	0	10 S	15.7	10 R-MR	2.0	0	20 MR	0	np	40 S	40 MS	np	20.0	–	0	0
		95/96	np	30 S	0	5 R	10 S	np	np	40 S	0	10 S	0	0	10.1	–	–	0	10 MS	90 S	0	0	20 MS	10 MS	17.4	0	0	0
		96/97	0	0	0	0	0	0	10 R	10 S	5 S	0	5 S	10 S	2.7	0	0	np	np	np	np	np	np	np	np	–	–	
	Mean														8.5	–	0.8								22.2			0.0
46	Debeira	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	5 MR	2.0	–	0	np	30 S	0	0	–	5.0	0	–	0
		93/94	10 S	40 S	np	10 S	tr S	0	np	np	np	30 S	0	0	11.5	5 R-MS	1.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	20 S	np	np	5 S	5 MR	np	np	np	0	40 S	0	0	9.4	30 MR-MS	12.0	0	np	0	np	0	0	0	0	0	5 MR	1.0
		95/96	np	20 R	0	20 R	0	np	np	20 S	0	0	0	0	2.3	–	–	0	10 MS	0	0	np	0	np	1.1	20 S	5 MR	11.0
		96/97	20 S	20 S	0	10 S	10 S	10 S	0	5 S	60 S	10 MS	20 MS	0	13.3	0	0	np	np	np	np	np	np	np	np		–	–
	Mean														7.3	–	3.8								1.5			2.4
47	Condor	92/93	0	0	np	np	np	np	np	np	tr MS	0	0	0	0.1	tr S	2.0	–	10 MS	np	30 S	0	0	tr MR	6.5	0	–	0
		93/94	10 S	0	np	tr S	tr S	0	np	np	np	40 MS-S	0	0	5.5	20 MS	16.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	10 S	np	np	tr MR-MS	tr S	np	np	np	tr S	20 MR	0	0	2.5	20 R-MS	4.0	0	np	5 S	np	0	25 MS	np	6.3	0	5 MR	1.0
		95/96	np	60 S	0	10 R	0	np	np	20 S	0	20 MR	0	0	10.0	–	–	0	5 R	0	0	0	0	0	0.1	0	0	0
		96/97	10 S	10 S	0	0	0	5 S	0	10 S	0	30 S	70 S	30 S	12.9	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														6.2	–	8.0								3.2			0.2
48	Condor 'S'	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr R	0.4	–	10 MS	np	20 MS	0	0	–	4.0	np	np	–
		93/94	tr S	0	np	tr S	tr S	0	np	np	np	20 MS	0	0	0.7	tr MS	0.8	0	np	0	10 MS	0	np	np	1.0	–	–	
		94/95	10 S	np	np	tr MR-MS	10 S	np	np	np	tr S	0	0	0	3.2	30 R-MR	6.0	0	np	0	np	0	40 MS	np	8.0	–	–	–
		95/96	np	tr MR	0	10 R	0	np	np	30 S	30 S	0	0	0	6.9	–	–	0	5 MS	0	80 S	0	0	0	12.0	0	–	0
		96/97	10 R	0	tr S	0	5 S	5 S	0	20 R	0	0	20 S	0	3.2	0	0	np	np	np	np	np	np	np	np	0	0	0
	Mean														2.2	–	1.8								6.3			0.0

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarznura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
49	*Triticum boeoticum* No. 600674	92/93	80 S	90 S	np	np	np	np	np	np	70 S	40 S	10 S	10 S	50.0	40 S	40.0	np	–	np	0	–	np	np		10 S		10.0
		93/94	80 S	80 S	np	80 S	60 S	80 S	np	np	np	90 S	80 S	10 S	73.8	0	0	0	np	0	0	0	np	np	0	–	–	
		94/95	tr S	np	np	60 S	80 S	np	np	np	60 S	60 S	30 S	10 S	41.7	30 S	30.0	0	np	0	np	–	–	np	0	–	–	–
		95/96	np	80 S	30 S	100 S	100 S	np	np	80 S	30 S	60 S	40 S	10 S	58.9	np	–	tr MS	80 S	20 MR	0	20 S	25 MS	0	18.5		60 S	60.0
		96/97	20 S	10 S	0	0	80 S	30 S	0	10 R	0	70 S	50 S	10 S	22.7	0	0	np	np	np	np	np	np	np	np	np	np	–
	Mean														44.9	–	23.3								6.2			14.0
50	*T. boeoticum* No. 600742	92/93	10 S	10 S	np	np	np	np	np	np	60 S	10 S	10 S	10 S	18.3	40 S	40.0	np	np	np	np	np	np	np	np	np	np	–
		93/94	80 S	10 R-MR	np	60 S	80 S	60 S	np	np	np	90 S	0	40 S	51.8	0		0	np	0	0	0	np	np	0	–	MR	0.8
		94/95	30 S	40 S	np	40 S	np	40 S	np	np	40 S	60 MS	40 S	40 S	44.8	30 S	30.0	0	np	0	np		–	np	0	–	60 S	60.0
		95/96	np	80 S	0	100 S	80 S	np	np	80 S	40 S	40 S	40 S	10 S	55.2			0	50 S	100 S	0	0	0	0	21.4	0	40 S	20.0
		96/97	60 S	40 S	0	0	0	20 S	20 S	5 MR	10 S	0	40 S	10 S	16.7	0	0	np	np	np	np	np	np	np	np	np	np	–
	Mean														42.5	–	23.3								5.4			16.2
51	*T. dicoccoides* No. 600363	92/93	10 MR-MS	10 MS-S	np	np	np	np	np	np	10 S	10 S	tr S	10 S	7.3	30 S	30.0	–	–	np	–			np		5 S	–	5.0
		93/94	80 S	0	np	80 S	80 S	80 S	np	np	np	0	0	10 S	41.3	0	–	0	np	30 S	20 S	0	np	np	12.5		5 MS	4.0
		94/95	0	np	np	tr S	20 S	np	np	np	20 S	60 S	10 S	10 S	17.1	40 S	40.0	0	np	40 S	np		–	np	10.0	–	60 S	60.0
		95/96	np	90 S	20 MS-S	100 S	80 S	np	np	20 S	40 S	40 S	10 S	10 S	45.1	–	–	0	80 S	20 S	100 S	tr MS	tr MS	0	29.0	–	40 S	40.0
		96/97	20 S	10 S	tr S	20 S	80 S	5 S	5 S	5 S	60 S	0	40 S	0	20.6	0	0	np	np	np	np	np	np	np	np	np	np	–
	Mean														27.7	–	23.3								11.3			21.8
52	*T. dicoccoides* No. 600375	92/93	10 MS	10 MR-MS	np	np	np	np	np	np	10 S	tr MR-MS	tr S	0	41.1	40 S	40.0	np	np	np	np	np	np	np	np	–		–
		93/94	90 S	0	np	90 S	80 S	0	np	np	np	0	0	10 S	46.3	0	–	0	np	30 S	10 S	0	np	np	10.0	–	20 MS	16.0
		94/95	0	np	np	10 S	30 S	np	np	np	10 S	80 S	10 S	0	164.0	30 MS	12.0	0	np	40 S	np	–	–	np	10.0	–	40 S	40.0
		95/96	np	80 S	10 S	100 S	80 S	np	np	20 S	80 S	40 S	10 S	10 S	47.8	–	–	tr MS	80 S	40 MS	0	20 MS	15 MS	0	20.0	0	40 S	20.0
		96/97	0	0	10 S	0	0	10 S	20 S	30 S	60 S	50 S	0	0	15.0	0	0	np	np	np	np	np	np	np	np	np	np	–
	Mean														33.3	–	13.0								10.0			15.2

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																									
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
53	*Triticum dicoccoides* No. 600679	92/93	90 S	40 MS	np	np	np	np	np	np	50 S	60 S	30 S	40 S	50.3	40 S	40.0		–	np	–	–	np	–	–		–	–
		93/94	90 S	0	np	90 S	80 S	90 S	np	np	np	0	0	10 S	66.3	0	0	0	np	10 S	10 S	0	np	np	5.0	–	30 S	30.0
		94/95	0	np	np	50 S	90 S	np	np	np	40 S	90 S	10 S	10 S	41.4	5 R-MR	1.0	0	np	50 S	np		–	np	12.5	–	40 S	40.0
		95/96	np	90 S	50 S	100 S	100 S	np	np	70 S	90 S	60 S	60 S	10 S	70.0		–	100 S	30 S	0	40 MS	80 S	10 S	80 S	36.0	80 S	60 MS	60.0
		96/97	50 S	30 S	tr S	0	0	0	10 S	5 S	40 S	10 S	tr S	0	12.4	0	0	np	np	np	np	np	np	np	np	np	np	–
	Mean														41.2		10.3								17.8			26.0
54	*T. dicoccoides* No. 600715	92/93	70 S	90 S	np	np	np	np	np	np	50 S	80 S	30 S	50 S	61.7	40 S	40.0	np	np	np	np	np	np	np	np	–		–
		93/94	90 S	40 S	np	90 S	80 S	90 S	np	np	np	0	0	0	48.8	0	–	0	np	30 S	10 S	0	np	np	10.0		10 MS	8.0
		94/95	80 S	np	np	30 S	80 S	np	np	np	60 S	0	0	0	35.7	50 S	50.0	tr MR	np	20 S	np	–	–	np	5.2	–	40 S	40.0
		95/96	np	90 S	50 S	100 S	100 S	np	np	60 S	90 S	0	10 S	10 R	50.0	–	–	50 S	100 S	80 S	0	40 MS	80 S	20 S	51.7	90 S		90.0
		96/97	–		–	–	–	–		–	–	–	–		np	0	0	np	np	np	np	np	np	np	np	np	np	–
	Mean														49.1	–	22.5								22.3			27.6
55	El-Neilain	92/93	10 S	20 S	np	np	np	np	np	np	40 S	10 S	0	0	13.3	20 S	20.0	np	60 S	np	0	0	80 S	–	28.0	–	–	
		93/94	10 S	0	np	10 S	tr S	tr S	np	np	np	30 S	10 S	30 S	11.8	40 MS-S	32.0	0	np	40 S	10 S	0	np	np	12.5	–	0	0
		94/95	20 S	np	np	10 MR	0	np	np	np	tr R	20 MR	0	0	4.6	10 R-MR	2.0	–	np	5 S	np	0	0	np	1.2	0	80 S	40.0
		95/96	np	tr MS	5 MR-MS	5 R	0	np	np	tr S	tr S	tr S	10 S	0	2.2	–	–	50 S	5 S	60 MS	0	0	10 MS	0	14.7	0	–	0
		96/97	5 S	tr S	tr S	0	10 S	10 S	10 S	5 S	tr S	0	80 S	30 S	14.7	0	0	np	np	np	np	np	np	np	np	np	np	–
	Mean														9.3	–	13.5								14.1			10.0
56	Baladi	92/93	70 S	90 S	np	np	np	np	np	np	50 S	70 S	90 S	40 S	68.3	30 S	30.0	np	np	np	np	np	np	np	np	–	–	–
		93/94	10 S	30 S	np	10 S	10 S	tr S	np	np	np	40 MS-S	0	0	11.8	30 MS-S	24.0	0	np	0	0	0	np	np	0	–	0	0
		94/95	10 S	Np	np	0	10 S	np	np	np	5 S	20 MR	10 S	0	4.7	30 MR-MS	12.0	0	np	0	np	0	0	np	0	–	–	
		95/96	np	70 S	0	10 MR-MS	50 S	np	np	70 S	40 S	40 S	10 S	0	27.1	–		0	0-5 R	50 MS	0	0	tr MS	0	5.6	0	5 MR	1.0
		96/97	0	0	0	0	10 S	10 S	0	0	0	40 S	70 S	30 S	16.7	0	0	np	np	np	np	np	np	np	np	np	np	–
	Mean														25.7	–	16.5								1.9			0.3

Appendix 1. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI‡	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
57	Mokhtar	92/93	–		np	np	np	np	np	np	–		–	–	–	–	–	–		np	–	–	np	–	–	0	–	0
		93/94	30 S	40 S	np	20 S	10 S	tr S	np	np	np	40 S	0	10 R	17.8	10 MR-MS	2.0	np	np	np	np	np	np	np	0	–	0	0
		94/95	20 S	np	np	10 MS	0	np	np	np	10 R	20 MR	10 R	10 R	4.8	20 MR-MS	4.0	–	np	0	np	0	tr MS	np	0.2	0	0	0
		95/96	np	30 S	0	60 S	70 S	np	np	70 S	40 S	30 MR	10 S	tr S	38.3	–		0	5 MS	30 S	0	0	5 MS	0	5.1	–	5 MR	1.0
		96/97	40 S	20 S	0	0	tr S	5 S	5 S	5 MS	60 S	0	70 S	tr S	17.3	0	0	np	np	np	np	np	np	np	np	0	0	0
	Mean														19.6	–	1.5								1.7			0.2
58	Aziz	92/93	–	–	np	np	np	np	np	np	–			–	np	–	–	–	–	np			np	–	0	0	–	0
		93/94	tr S	10 S	np	tr S	tr S	tr S	np	np	np	50 S	0	0	11.3	30 MS	24.0	np	np	np	np	np	np	np	np	–	0	0
		94/95	5 S	np	np	20 MS	0	np	np	np	tr S	20 MR	0	0	3.9	20 MR-MS	8.0	–	np	0	np	0	0	np	0	0	–	0
		95/96	np	70 S	0	40 MS-S	50 S	np	np	60 S	0	0	10 S	0	24.7	–	–	0	5 R	90 S	0	0	0	0	12.9	0	5 MR	1.0
		96/97	20 MS	10 MS	0	0	tr S	5 S	0	5 R	10 S	0	50 S	0	7.7	0	0	np	np	np	np	np	np	np	np	0	0	0
	Mean														11.9	–	7.5								4.3			0.2
59	Marib 1	92/93	–	–	np	–	np	np	np	np	–	–		–	np	–	–	–	–	np	–	–	np		–	0	–	0
		93/94	tr S	0	np	tr S	10 S	tr S	np	np	np	0	0	0	1.8	20 R-MR	4.0	np	np	np	np	np	np	np	np	–	0	0
		94/95	10 MS	np	np	0	0	np	np	np	0	0	0	0	0.3	10 R-MR	2.0	–	np	0	np	0	0	np	0	–	0	0
		95/96	np	0	0	0	0	np	np	tr S	0	0	0	0	0.3	–	–	0	5 R	30 S	0	0	0	0	4.6	0	5 MR	1.0
		96/97	0	0	0	0	10 S	10 S	0	0	0	0	tr MS	0	1.7	0	0	np	np	np	np	np	np	np	np	0	0	0
	Mean														1.0	–	1.5								2.3			0.2
60	Little Club	92/93	50 S	40 S	np	np	np	np	np	np	70 S	40 S	40 S	40 S	33.2	40 S	40.0	–	40 S	np	0	–	np	–	8.0	0	–	0
		93/94	80 S	90 S	np	40 S	80 S	90 S	np	np	np	90 S	10 S	30 S	61.3	50 S	50.0	np	np	np	np	np	np	np	np	–	0	0
		94/95	40 S	np	no	40 S	40 S	np	np	np	40 S	80 S	40 S	30 S	44.3	20 MS	26.0	–	np	40 S	np	0	50 MS	np	10.0		100 S	100.0
		95/96	np	80 S	70 S	100 S	80 S	np	np	0	40 S	80 S	40 S	40 S	58.9	–		tr MS	90 S	20 S	60 S	0	30 MS	0	28.0	0	20 MS	8.0
		96/97	60 S	40 S	40 S	40 S	80 S	40 S	60 S	40 S	40 S	60 S	70 S	60 S	52.5	20 MS	16.0	np	np	np	np	np	np	np	np	–	–	–
	Mean														50.0		33.0								8.7			21.6

Appendix 2. Severity† of stem rust (*Puccinia graminis*) and type of infection of cultivars/lines in the Nile Valley and Red Sea Wheat Rusts Nursery (NVRSWRTN) at different planting Site, 1992/93–1996/97.

No.	Cultivar/ Line	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
	Lr or *Sr* gene		Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
1		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	0	np	0	60 S	–	60
	Thatcher^6 × Webster	93/94	0	0	np	0	0	0	np	np	np	0	0	0	–	5 MR-MS	4	np	0	np	80 S	0	tr MS	np	13.6	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	5 MS	4	0	np	0	0	0	10 MS	np	2	10 MS		8
	Lr 2a	95/96	np	0	0	0	tr R	np	np	0	0	0	0	0	0.08	–	–	0	5 S	0	10 S	0	10 MS	5 MS	3.8	–	5 R	1.0
		96/97	0	0	tr S	0	0	tr S	tr S	0	tr MR	0	0	0	1.76	tr MR	0.8	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.4	–	1.8								4.9			13.9
2		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	40 S	–	40
	Thatcher^6 × Hussar	93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	20 MS-S	16	0	0	np	40 S	0	0	np	10	tr R	–	0.4
		94/95	0	np	np	tr S	0	np	np	np	0	0	0	0	0	10 MS-S	8	0	np	0	np	0	0	np	0	tr R		0.4
	Lr 11	95/96	np	0	0	0	0	np	np	0	tr S	0	0	0	0	–	–	0	5 S	0	0	0	5 MS	10 MS	2.4	–	10 S	10
		96/97	0	0	0	0	5 S	tr S	0	0	0	0	0	0	0.6	5 MR	2	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.1	–	5.2								3.1			10.2
3		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	10 S	np	np	np	10	20 R	–	4
	Thatcher^6 × Transfer	93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	5 MR-MS	2	np	np	np	10 S	np	np	np	10	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	10 MS-S	8	0	np	0	np	0	0	np	0	tr R		0.4
	Lr 9	95/96	0	0	0	0	0	np	np	0	0	0	0	0	0		–	0	5 S	0	0	0	5 MS	20 S	4.1	–	50 S	50
		96/97	0	0	0	0	0	5 S	0	tr S	0	0	0	0	0.6	tr R	0.9	np	np	np	np	np	np	np	np	0	0	0
	Mean														0.1	–	2.2								6.0			10.9
4		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	tr R	–	0.4
	Thatcher^6 × Klein Lucero	93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	5 MR-MS	2	0	0	np	60 S	0	0	np	10	tr R	–	0.4
		94/95	0	np	np	tr S	0	np	np	np	0	0	0	0	0	5 MS	4	0	np	0	np	0	tr MS	np	0.4	tr R	–	0.4
	Lr 17	95/96	np	0	0	0	tr R	np	np	0	0	0	0	0	0.04	–	–	0	5 S	0	5 MS	0	10 MS	5 S	3.1	–	0	0
		96/97	0	0	0	0	0	5 S	0	0	0	0	0	0	0.4	5 MR	2	np	np	np	np	np	np	np	np	–		
	Mean														0.1	–	1.6								3.4			0.2

† Severity = percent coverage with pustules.
‡ CI was used for Sudan since data were available from one site only.
tr = trace – 100; Infection type: R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible; ACI = average coefficient of infection; CI = coefficient of infection; np = not planted; – = reaction type not readable due to coverage of the leaf plant by other foliar diseases.

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																									
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
5	Thatcher^6 · Africa 13	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	np	np	0.4	np	0.4	20 MR	-	8
		93/94	0	0	np	10 S	0	0	np	np	np	0	0	0	1.3	5 MR-MS	2	np	np	np	60 S	10 S	10 S	np	1	tr R		0.4
		94/95	0	np	np	tr MS	tr S	np	np	0	0	0	0	0	0.5	0	0	0	np	0	np	0	0	np	0	tr R	–	0.4
	Lr 18	95/96	0	0	0	5 MS	tr R	np	np	0	0	0	0	0	0.5	--		0	10 S	0	10 S	0	5 MS	10 S	4.9	0	50 MR	10
		96/97	0	0	0	0	5S	tr S	0	0	0	0	0	0	0.6	0	0	np	np	np	np	np	np	np	np	0	0	0
	Mean														0.6		0.4								26.7			3.7
6	Thatcher^6 · RL 54006	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	10 R	--	2.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	5 MR-MS	2	np	np	np	40 S	0	0	np	10	tr R	np	0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	10 MS	16	0	np	0	np	0	0	np	0	tr R	np	0.2
	Lr 21	95/96	np	0	0	0	0	np	np	0	0	0	0	0	0		--	0	15 S	0	20 S	0	5 MS	20 S	8.4	0	10 S	5.0
		96/97	0	0	0	0	0	5 S	0	0	0	0	0	0	0.6	0	0	np	np	np	np	np	np	np	np	-	--	-
	Mean														0.1	–	3.6								6.1			1.5
7	Thatcher^6 · Lee 310	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	60 MR		24
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	20 MS-S	16	np	np	np	40 S	tr S	np	np	22	tr R	-	0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	5 MS	1.0	0	np	0	np	0	tr MS	np	0.4	tr R	--	0.4
	Lr 23	95/96	np	0	0	0	0	np	np	0	0	0	0	0	0		–	np	5 S	0	20 S	np	tr MS	20 S	11.7	0	tr S	0.2
		96/97	0	0	0	0	0	tr S	0	0	0	0	0	0	0.3	0	0	np	np	np	np	np	np	np	np	–	–	-
	Mean														0.1	-	3.4								33.4			5.0
8	Agent	92/93	tr S	tr S	np	np	np	np	np	np	tr S	0	0	0	1	0	0	np	np	np	np	np	np	np	np	10 R	--	2.0
		93/94	0	0	np	0	0	np	np	np	np	0	0	0	0	30 MS-S	24	np	np	np	20 S	0	np	np	10	tr R	--	0.4
	Lr 24 and *Sr 24*	94/95	0	np	np	tr S	0	np	np	np	0	0	0	0	0.3	30 S	30	0	np	0	np	0	0	np	0	0	5 MS	2.0
		95/96	np	0	0	0	0	np	np	tr S	0	0	0	0	0.2	-	--	0	30 S	0	30 S	0	tr MS	30 S	13.1	0	tr S	2.0
		96/97	0	0	0	0	0	tr S	0	0	0	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	–	-	–
	Mean														0.3	--	10.8								7.7			1.3

Appendix 2. (Cont'd)

No.	Cultivar/ Line; *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
9	St. 1.25, Tc^6 × *Lr 26*	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	10 R	–	2.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	10 MR-MS	4	np	np	np	40 S	np	np	np	20	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	tr R	0.2	0	np	0	np	tr MS	0	np	0.4	tr R	–	0.4
	Lr 26 and *Sr 31*	95/96	np	np	np	0	0	np	np	0	0	0	0	0	0	–	–	0	5 MS	0	5 MS	0	5 MS	10 S	3.1	–	5 MS	4.0
		96/97	0	0	0	np	5 S	0	0	0	0	0	0	0	0.6	0	0	np	np	np	np	np	np	np	np	–	–	
	Mean														–	–	–								7.8			1.3
10	Prelude × Reliance	92/93	0	0	np	np	np	0	np	np	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	tr R	–	0.4
		93/94	np	np	np	0	0	np	np	np	np	0	0	0	0	50 MS-S	40	np	np	np	80 S	0	np	np	20	tr R	–	0.4
		94/95	np	np	np	5 S	0	np	np	np	0	0	0	0	0.7	5 S	5	0	20 S	0	0	0	30 MS-S	10 S	12	tr R		0.4
	Sr 5	95/96	np	0	0	0	0	np	np	0	0	0	0	0	0	–	–	np	np	np	np	np	np	np	7.7		–	–
		96/97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.1	–	11.3								10.0			0.2
11	Line Dsel	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	–	np	–	80 S	0	tr MS	–	13.6	20 R	–	4.0
		93/94	0	0	np	0	0	10 S	np	np	np	0	0	0	1.3	50 S	50	30 S	0	np	80 S	0	10 S	np	29	tr R	–	0.4
		94/95	0	np	np	5 S	0	np	np	np	0	0	0	0	0.6	40 S	40	5 R	0	np	np	0	10 MS-S	np	2.3	tr R	5 MR	1.2
	Sr 6	95/96	np	0	0	0	0	np	np	0	0	0	0	0	0	–	–	0	5 R	20 S	10 MR	0	tr MS	5 MS	4.4	0	0	0
		96/97	0	0	0	0	10 S	0	0	0	0	0	0	0	0.8	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.5	–	22.5								12.3			1.1
12	Vernstein	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	10 S	10	np	np	np	np	np	np	np	–	20 S	–	20
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	30 MS-S	24	60 S	np	np	100 S	0	20 S	np	45	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	60 S	60	10 R	0	np	np	0	0	np	0.2	10 MS	–	8
	Sr 9e	95/96	np	0	0	0	0	np	np	0	tr S	0	0	0	0.2	–		20 S	5 R	20 S	20 S	0	0	5 MR	23.6	tr R	5 MR	2.4
		96/97	0	0	0	0	0	10 S	0	0	tr MR	10 S	0	0	0.7	0	0	np	np	np	np	np	np	np	np	–	–	
	Mean														0.2	–	16.8								23.2			6.2

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2	np	np	np	np	np	np	np	np	10 R	–	2.0
	Line AG	93/94	0	0	np	0	0	10 S	np	np	np	0	0	0	1.3	30 S	30	20 S	np	np	100 S	0	tr S	np	30.5	tr R		0.4
13		94/95	0	np	np	5 S	0	np	np	np	np	0	10 S	0	2.1	30 S	30	10 R	np	np	np	10 MS	tr MS	np	1.9	5 S	–	5.0
	Sr 11	95/96	np	0	0	0	0	np	np	5 S	0	10 S	0	5 S	2.2	–		10 MS-S	10 S	10 S	40 S	0	0	5 S	10.4	0	0	0
		96/97	0	0	0	0	20 S	0	0	0	0	0	5 S	10 S	2.9	0	0	np	np	np	np	np	np	np	np			-
	Mean														6.9	–	12.4								14.3			1.5
		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2	np	np	10 S	5 S	np	np	np	7	5 S	–	5.0
	Einkorn	93/94	0	0	np	np	tr S	0	np	np	np	0	0	0	0.3	60 S	60	30 S	np	np	80 S	tr MS	tr MS	np	25.6	tr R		0.4
14		94/95	0	np	np	0	0	np	np	tr S	0	tr S	0	tr S	0.8	60 S	60	30 MS	np	0	np	0	30 MS	np	12	10 S	–	10.0
	Sr 21	95/96	np	0	0	0	0	5 S	0	0	0	tr S	0	0	0.8	–	–	30 MS-S	80 S	50 S	60 S	0	10 MS	5 MS	32.3	30 S	–	30.0
		96/97	0	0	0	0	0	tr S	0	0	0	0	tr S	0	0.3	0	0	np	np	np	np	np	np	np	np			-
	Mean														0.4	–	24.4								19.0			7.3
		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	0	0	np	np	np	0	60 S	–	60.0
	LC *Sr 25* Ars	93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	100 S	100	0	np	np	80 S	5 MS	tr MS	np	21.4	tr R		0.4
15		94/95	np	np	np	0	0	np	np	np	np	0	0	0	0	60 S	60	0	np	0	np	50 S	40 S	np	22.5	10 S	-	10.0
	Sr 25	95/96	np	0	0	0	0	np	np	0	0	0	0	0	0	–	–	30 MS	80 S	10 MS	30 S	0	20 MS	30 S	26.9	0	0	0
		96/97	0	0	0	0	0	5 S	0	0	0	0	0	0	0.4	0	0	np	np	np	np	np	np	np	np			-
	Mean														0.1		32.0								17.7			14.0
		92/93	tr S	10 S	np	np	np	np	np	np	10 S	tr S	0	0	4	10 S	10	np	np	np	30 S	10 S	np	np	15	40 S		40.0
	Eagle	93/94	tr S	0	np	0	0	10 S	np	np	np	5 S	0	0	2.1	50 S	50	np	np	np	np	tr R	np	np	0.2	tr R		0.4
16		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	10 MS-S	8	0	np	0	np	0	tr MS	np	0.4	0	60 MS	48.0
	Sr 2 and *Sr 26*	95/96	np	0	0	0	0	np	np	0	0	10 S	0	0	1.1	–	–	tr MS	60 S	10 S	40 S	0	0	20 S	18.8	20 S	0	20.0
		96/97	0	0	0	0	10 S	5 S	0	0	40 S	10 S	0	0	7.9	tr MS	1.6	np	np	np	np	np	np	np	np		–	–
	Mean														1.5	–	14.0								8.6			19.0

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
17	W2691	92/93	tr S	0	np	np	np	np	np	np	tr S	tr S	0	0	1.0	30 S	30	np	np	np	20 S	np	np	np	20	5 MR	–	0.6
		93/94	0	tr S	np	0	0	np	Np	np	np	tr S	0	0	0.5	80 S	80	np	np	np	np	np	np	np	np	tr R	–	0.4
	Sr 28 Kt *Sr 27*	94/95	tr S	np	np	5 S	5 S	np	np	np	np	0	0	0	1.7	80 S	80	0	np	0	np	0	0	np	0	5 MS	80 MS	64.0
		95/96	np	0	tr S	0	30 S	np	np	40S	tr S	tr S	0	0	8.4	–		20 MS	100 S	10 S	80 S	0	50 S	80 S	50.3	20 S	20 MS	16.0
		96/97	0	0	0	0	0	10 S	0	0	tr S	tr S	0	0	1.2	10 MR	4	np	np	np	np	np	np	np	np	–	–	–
	Mean														2.6		38.8								23.4			16.2
18	Gamut	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	50 S	np	np	np	5	50 S	–	50.0
		93/94	0	0	np	0	0	tr S	np	np	np	0	0	0	0.3	40 MS-S	32	np	np	np	np	np	np	np	2.2	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	10 R-MR	2	0	np	5 S	np	0	tr MS	np	1.0	tr R	20 MS	8.1
	Sr Gt	95/96	np	0	tr S	0	0	np	np	0	tr S	tr S	0	0	0.7	–	–	0	MR	0	0	0	0	5 MS	2.2	0	20 MS	8.0
		96/97	0	0	0	0	0	tr S	0	0	tr S	0	tr S	0	0.7	0	0	np	np	np	np	np	np	np	np	–	–	
	Mean														0.3	–	6.8								2.7			13.13
19	*Triticum timopheevii*	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	np	0	np	np	np	np	np	np	np	np	–	–	–
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	30 MS-S	24	20 S	–	–	100 S	0	0	np	20	tr R	0	0.4
		94/95	0	np	np	0	5 S	np	np	np	0	0	0	0	0.7	20 S	70	20 MR	np	0	np	0	30 S	np	9.5	0	10 S	10.0
	Sr Tt-1 (36)	95/96	np	np	0	0	0	np	np	0	0	0	0	0	0	–	–	30 MS-S	60 S	5 MS	0	0	10 MS	20 S	16.6	0	10 S	10.0
		96/97	0	0	0	0	0	0	10 MS	0	0	0	0	0	0.7	0	0	np	np	np	np	np	np	np	np	–		–
	Mean														0.3	–	18.8								15.4			4.0
20	Giza 155	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	np	np	np	np	0	20 MR	–	8.0
		93/94	np	np	np	0	0	tr MS	np	np	np	0	0	0	0.2	20 MR-MS	8	np	np	np	np	np	np	np	0	tr R	-	0.4
		94/95	np	np	0	0	0	np	np	np	np	0	0	0	0	tr MR	0.8	np	np	np	np	np	np	np	0	0	–	0.0
		95/96	np	0	0	0	0	tr S	10 MS	0	0	0	0	0	0.9	–	–	np	np	0	np	0	0	np	0	5 S	40 MS	18.5
		96/97	0	0	0	0	0	5 S	0	0	0	0	0	0	0.4	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.3	–	1.8								0			5.4

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweet	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
21	Giza 157	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2	0	0	0	30 S	0	0	np	5.8	20 S		70.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	30 MS-S	24	0	0	np	30 S	0	0	tr MS	5.1	tr R	-	0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	30 MS-S	21	0	np	0	0	0	tr MS	tr MS	0.8	tr S	-	0.4
		95/96	np	0	0	0	0	np	np	0	0	0	0	0	0		-	0	50 S	0	10 MR	0	tr MS	0	7.9	20 MS-S	40 MS	24.0
		96/97	0	0	0	0	0	0	0	0	tr S	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	-	-	
	Mean														0.0		10.0								4.9			18.9
22	Giza 162	92/93	10 S	10 S	np	np	np	np	np	np	0	0	0	0	3.3	0	0	np	np	np	np	np	np	np	np	50 S		50.0
		93/94	0	0	np	0	0	10 S	np	np	np	0	0	0	1.3	30 MS-S	24		0	np	100 S	0		np	25	tr R	-	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	10 R-MR	2	0	np	5 S	np	0	tr MS	np	1.7	0	0	0
		95/96	np	10 S	0	0	0	np	np	0	0	0	0	0	1.1	-	-	0	20 S	0	5 MS	0	tr MS	10 MS	11.9	0	0	0
		96/97	0	0	0	0	0	5 S	20 S	0	0	0	0	0	6.3	0	0	np	np	np	np	np	np	np	np	-	-	
	Mean														2.4	-	5.2								12.9			10.1
23	Giza 163	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2	np	np	np	np	np	np	np	-	10 R		4.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	50 S	50	np	0	np	40 S	0	0	np	10	tr R	-	0.4
		94/95	0	np	0	0	0	np	np	np	np	0	0	0	0	30 MS-S	24	0	np	5 S	np	0	0	np	1	tr R	0	0.2
		95/96	0	0	0	0	tr S	np	np	0	0	0	0	0	0.2	-	0	0	80 S	0	5 MS	0	30 S	10 S	17.7	0	0	0
		96/97	0	0	0	0	0	0	10 S	0	0	0	0	0	0.8	np	0	np	np	np	np	np	np	np	np	-	-	
	Mean														0.2	-	19.0								7.2			0.9
24	Giza 164	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	20 S	-	20.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	30 MS-S	24	-	0	np	80 S	0	0	np	20	tr R	-	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	10 MR-MS	16	0	np	0	np	0	20 MS	np	9	tr R	0	0.4
		95/96	0	0	0	np	0	np	np	tr MS	0	0	0	0	0.2	-	-	0	50 S	0	0	0	5 MS	20 S	10.6	0	0	0
		96/97	0	0	0	np	0	5 MS	40 S	0	0	0	0	0	3.7	0	0	np	np	np	np	np	np	np	np	0	0	0
	Mean														0.9	-	10								8.7			4.2

Appendix 2. (Cont'd)

No.	Cultivar/ Line	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
	Lr or *Sr* gene		Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
25	Giza 165	92/93	0	0	np	0	0	0	np	np	np	0	0	0	0	5 S	5	np	np	np	80 S	5 MS	np	np	42	60 S		60.0
		93/94	0	np	np	0	0	np	np	np	np	0	0	0	0	30 MS-S	24	–	0	np	40 S	0	0	np	10	tr R	–	0.4
		94/95	np	np	np	5 S	0	np	np	np	0	0	0	0	0.8	30 MR-MS	12	0	np	0	np	0	10 MS	np	2	tr R	0	0.2
		95/96	np	0	0	0	0	np	np	0	np	0	0	0	0	–	np	0	90 S	0	20 S	0	5 MS	20 S	19.1	0	0	0
		96/97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.2	–	8.2								18.3			12.2
26	Sakha 8	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr R	0.4	np	np	np	np	np	np	np	0	30 MS	–	24.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	50 MS-S	40	0	0	np	40 S	0	0	np	10	tr R	–	0
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	50 MS-S	40	0	np	0	np	0	20 MS	np	9	tr R	0	0
		95/96	np	0	0	0	0	10 S	0	0	np	0	0	0	1.1	–	–	0	90 S	0	10 S	0	10 MS	5 MS	16	0	0	0
		96/97	0	0	0	0	0	0	20 S	0	0	0	0	0	1.7	0	0	np	np	np	np	np	np	np	np	–		–
	Mean														0.6	–	16.1								8.8			4.8
27	Sakha 69	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr R	0.8	np	np	np	np	np	np	np	0	10 MS	–	8.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	30 MR-MS	12	0	0	np	20 MR	0	0	np	9	tr R		0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	40 MS-S	32	0	np	0	np	0	tr MS	np	0.8	tr R	–	0.4
		95/96	np	0	0	0	0	np	np	tr R	np	0	0	0	0.04		–	0	90 S	0	SR	0	tr MS	5 MR	13.4	20 MS	0	8
		96/97	0	0	0	0	0	tr S	50 S	0	0	0	0	0	4.3	0	0	np	np	np	np	np	np	np	np	–		–
	Mean														0.9	–	9.0								5.8			3.9
28	Sakha 92	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	np	np	np	np	0	20 MS	–	16.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	20 MS-S	16	0	0	np	20 MR	0	0	np	2	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	20 MR-MS	8	0	np	0	np	0	0	np	0	tr R	20 MS	8.2
		95/96	np	0	0	0	0	np	np	0	0	0	0	0	0	–		0	80 S	0	30 MS	0	tr MS	5 MR	15.7	0	0	0
		96/97	0	0	0	0	0	tr S	0	0	0	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.1	–	4.8								4.4			4.9

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site Egypt: Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	Sudan‡: New Halfa	CI	Ethiopia: Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Yemen: Dhamar	Seiyun	ACI
		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	0	0	np	0	0	0	np	0	50 MS	–	40.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	40 MS-S	32	0	0	np	30 MR	0	0	np	2.4	tr R		0.4
29	Gemmeiza 1	94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	40 MR-MS	16	0	np	0	np	0	0	np	0	tr R	0	0.2
		95/96	np	0	0	0	0	np	np	0	0	0	0	0	0		–	0	80 S	0	100 S	15 MS	0	5 MS	28.0	0	0	0
		96/97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	–		–
	Mean														0	·	9.6								7.6			8.1
		92/93	20 S	100 S	np	np	np	np	np	np	30 S	60 S	10 S	10 S	35	40 S	40	20 S	20 S	np	20 S	30 S	10 S	np	20.0	50 S	–	50.0
	Triticum	93/94	20 S	40 S	np	30 S	60 S	20 S	np	np	np	20 S	10 S	10 S	32.5	100 S	100	10 S	30 S	np	30 S	40 S	tr S	np	22.4	30 MS		24.0
30	*spelta*	94/95	40 S	np	np	50 S	10 S	np	np	np	np	10 S	10 S	10 S	21.7	100 S	100	tr MS	np	0	np	0	20 MS	np	4.4	5 MS	10 S	0
	saharense	95/96	np	30 S	30 S	30 S	30 S	np	np	40 S	10 S	60 S	10 S	10 S	30.0			20 S	10 S	30 S	100 S	0	20 S	30 S	37.1	20 S	10 S	15
		96/97	20 S	30 S	30 S	np	60 S	40 S	0	20 S	10 S	40 S	10 S	10 S	21.7	20 S	20	np	np	np	np	np	np	np	np	–	–	–
	Mean														28.2		52.0								21.0			31.8
		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2	np	np	np	5 S	0	np	np	2.5	20 S	–	20.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	80 MS-S	64	20 S		np	80 S	0	0	tr MR	16.8	tr R	-	0.4
31	Beni Suef 1	94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	20 S	70	tr S	np	20 S	np	0	10 MS	np	5.1	tr MS	20 MS	8.5
		95/96	np	0	0	0	0	np	np	0	0	0	0	0	0			0	100 S	10 S	60 S	0	20 S	60 S	35.7	20 S	20 MR	29.0
		96/97	0	0	0	0	5 S	10 S	0	0	0	0	0	0	1.3	0	0	np	np	np	np	np	np	np	np		–	–
	Mean														0.3	·	26.8								15.0			11.6
		92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	10 S	10	np	np	np	0	0	np	np	0	40 S		40.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	40 S	40	10 S	–	np	80 S	10 S	0	–	21.7	tr R	–	0.4
32	Sohag 1	94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	80 S	80	tr MR	np	20 S	np	0	10 MS	np	7.4	50 S	0	25
		95/96	np	0	0	0	0	np	np	0	0	0	0	0	0	–		0	90 S	20 S	80 S	0	tr MS	50 S	34.5	0	0	0
		96/97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0	–	26.0								15.9			13.1

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																									
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	*Ismailia*	*El-Serw*	*Zarzoura*	*Gemmeiza*	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
33	Sohag 2	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	40 S	40	np	np	np	0	0	np	np	0	20 R	–	4.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	50 MS-S	40	30 S	–	np	100 S	20 S	5 S	50 MS	33.7	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	90 S	90	10 MS	np	20 S	np	0	40 S	np	17	60 S	0	30
		95/96	np	0	0	0	0	np	np	0	0	0	0	0	0	–		0	100 S	30 S	60 S	0	50 S	90 S	47.1	20 S	0	35
		96/97	0	0	0	np	tr S	30 S	np	0	0	0	0	0	2.7	0	0	np	np	np	np	np	np	np	np	–	–	-
	Mean														0.5	–	34.0								24.5			15.9
34	Sohag 3	92/93	0	0	np	np	np	np	np	np	tr S	0	0	0	0.3	40 S	40	np	np	np	0	0	np	np	0	20 R		4.0
		93/94	0	10 S	np	0	0	10 S	np	np	np	10 S	0	0	3.8	80 MS-S	64	20 S	np	np	100 S	40 S	0	tr MR	40.2	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	tr S	0	0.2	90 S	90	20 MS	np	0	np	0	30 S	np	10.2	10 S	20 S	15
		95/96	np	0	0	0	0	10 S	0	0	tr S	tr S	0	0	1.6	–	–	0	100 S	30 S	40 S	0	10 MS	80 S	36.9	50 S	20 S	35
		96/97	0	10 S	0	0	10 S	20 S	0	0	10 S	20 S	0	0	np	0	0	np	np	np	np	np	np	np	np	–	–	
	Mean														1.2	–	38.8								21.9			10.1
35	Gemmeiza 3	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2	np	np	np	0	0	np	np	0	80 S	–	80.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	20 MS-S	16	20 S	–	np	100 S	5 S	0	np	25	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	60 MS	48	tr MS	np	20 S	np	0	0	np	5.4	tr R	–	0.4
		95/96	np	0	0	0	0	np	np	0	0	0	0	0	0	–	–	0	50 S	5 S	0	0	tr MS	5 MS	5.8	0	0	0
		96/97	0	0	0	0	0	0	0	0	tr S	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	–		–
	Mean														0.1	–	13.2								9.1			16.1
36	Giza 160	92/93	10 S	10 S	np	np	np	np	np	np	0	tr S	0	0	2	tr S	2	np	np	np	np	np	np	np	np	10 R	–	2.0
		93/94	10 S	tr S	np	0	0	20 S	np	np	np	tr S	0	0	4.3	50 MS-S	40	0	0	np	20 S	0	20 MS	np	9	tr R	–	0.4
		94/95	tr S	np	np	0	10 S	np	np	0	tr S	tr S	0	0	2.3	20 MS	16	0		0	np	0	10 MS	np	2	tr R	0	0.2
		95/96	np	0	0	0	10 S	np	np	np	np	10 S	0	0	2.2	–	–	0	20 S	0	10 MR	0	20 MS-S	10 MS	14	0	0	0
		96/97	0	tr S	0	0	tr S	20 S	0	0	10 S	10 S	0	0	3.7	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														2.7	–	11.6								6.3			0.5

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
37	Enkoy	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	np	np	0	80 S	–	80.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	10 R-MR	2	-	–	np	30 S	0	25 S	-	27.5	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	tr MR	0.8	tr MS	np	0	np	20 MS	50 S	np	13.8	0	0	0
		95/96	np	0	0	0	0	np	np	0	np	0	0	0	0			0	5 R	0	10 S	0	0	0	1.6	0	0	0
		96/97	0	0	0	0	0	tr S	0	0	0	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	–	–	
	Mean														0.1		0.6								14.2			16.1
38	K 6890-B	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	np	np	0	40 S	–	40.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	tr S	0.4	0	0	np	0	0	0	np	0	tr R		0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	tr R	0.4	0	np	0	np	0	0	np	0	tr R	0	0.4
		95/96	np	0	0	0	0	np	np	10 S	np	0	0	0	1.1			0	0	0	0	0	0	10 MS	1.1	0	0	0
		96/97	0	0	0	0	tr S	0	0	0	0	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	–	–	
	Mean														0.3		0.2								0.3			8.2
39	Dashen	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	np	np	0	10 R	-	2.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	tt MR-MS	0.8	0	0	np	0	0	35 S	np	8.8	tr R	-	0.4
		94/95	0	np	np	5 S	0	np	np	np	0	0	0	0	0.7	tr R-MR	0.4	0	np	0	np	0	0	np	0	tr R	0	0.2
		95/96	np	0	0	0	0	np	np	30 S	np	0	0	0	3.3			0	5 MS	5 S	80 S	0	0	tr MR	12.6	0	0	0
		96/97	0	0	0	0	0	tr S	0	0	0	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.8		0.2								5.4			0.5
40	ET 13	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	np	np	0	40 R	–	8.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	tr MR	0.8	0	0	np	5 S	tr MS	0	np	1.7	tr R	–	0.4
		94/95	0	np	np	0	tr MS	np	np	np	0	0	0	0	0.2	tr MR	0.8	0	np	5 S	np	0	0	np	1.2	tr R	0	0.2
		95/96	0	0	0	0	0	np	np	10 S	np	0	0	0	1.1	–	–	0	5 R	0	5 MR	0	0	10 MS	1.6	0	0	0
		96/97	0	0	0	0	0	0	0	tr S	0	0	0	0	0.1	0	0	np	np	np	np	np	np	np	np	–	–	-
	Mean														0.3	–	0.3								1.1			0.8

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
41	K 6295-4A	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	np	np	0	40 MS	–	32.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	tr MR	0.8	0	0	0	0	0	0	np	0	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	tr R	0.2	0	np	0	np	0	0	np	0	tr R	0	0.4
		95/96	np	np	np	np	0	np	np	30 S	np	0	0	0	3.3	–	–	0	0	0	10 MS	0	0	5 MR	1.4	0	0	0
		96/97	0	0	0	0	0	0	0	0	tr S	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.7	–	0.2								0.4			6.6
42	C.T. 71/CII	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	np	np	0	40 R		4
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	0	0	0	0	0	10 S	0	0	np	1.7	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	0	0	0	0	0	30 MS-S	24.0	0	np	0	np	0	5 MS	np	1.0	50 S	0	25
		95/96	np	0	0	0	0	np	np	10 S	np	0	0	0	1.1	–	–	0	5 MS	0	5 MS	0	0	5 MR	1.4	0	0	0
		96/97	0	0	0	0	0	20 S	0	0	0	0	0	0	1.7	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.6	–	4.8								1.0			5.9
43	Bohai	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2	np	np	np	0	0	np	np	0	20 R	–	4.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	40 MR-MS	16	0	0	0	5 MR	0	0	np	1	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	10 MR-MS	4	0	np	20 S	np	0	0	np	5	tr R	0	0.2
		95/96	np	0	0	0	0	np	np	20 S	0	0	0	0	2.2	–	–	0	5 R	0	60 S	0	0	5 MR	9	tr R	0	0.2
		96/97	0	0	0	0	0	5 S	0	0	0	0	0	0	0.4	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.5	–	4.4								3.8			1.0
44	Cocorit 71	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr S	2	np	np	np	0	0	np	np	0	30 S	–	30.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	30 MR-MS	12	0	0	0	10 MR	0	tr MR	np	0.8	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	20 MR-MS	8	0	np	20 S	np	0	0	np	5	tr R		0.4
		95/96	np	0	0	0	0	np	np	60 S	0	0	0	0	6.7	–	–	0	5 MR	0	0	0	0	20 MR	1.4	tr R	0	0.2
		96/97	0	0	0	0	5 S	10 S	0	0	0	0	0	0	1.3	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														1.6	–	4.4								1.8			6.2

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
45	DZ 04-118	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	np	np	0	20 S		20.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	30 MS-S	24	30 S	0	0	100 S	10 MS	0	np	23	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	20 R-MR	8	0	np	20 S	np	tr MR	40 S	np	17	tr R	0	0.2
		95/96	np	0	0	0	0	np	np	40 S	0	0	0	0	4.4	-	.	0	5 MR	10 MS	0	0	0	50 MR	2.3	tr R	0	0.2
		96/97	0	0	0	0	0	0	0	tr S	0	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.9	–	6.8								10.6			4.2
46	Debeira	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	np	np	0	60 S	–	60.0
		93/94	0	0	np	0	tr S	10 S	np	np	np	np	0	0	1.5	5 R-MR	1	0	0	np	20 MR	0	0	tr MR	1.5	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	tr MS	1.6	0	np	0	np	0	0	np	0	tr R	0	0.2
		95/96	np	0	0	0	0	np	np	20 S	0	0	0	0	2.9	–		0	10 MS	0	5 MR	0	tr MS	20 MS	3.9	tr R	0	0.2
		96/97	0	tr S	0	0	0	0	0	tr S	20 S	10 S	0	0	2.8	0	0	np	np	np	np	np	np	np	np		–	–
	Mean														1.4	–	0.5											12.2
47	Condor	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	tr MS	1.6	np	np	np	20 S	0	np	np	5	80 S	-	80.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	20 R-MR	4	0	0	np	0	0	0	tr MR	0.1	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	0	0	0	0	0	0	tr MR	0.8	0	np	0	np	0	0	np	0	0	0	0
		95/96	np	0	0	0	0	np	np	20 S	0	0	0	0	2.2	-	–	0	35 S	0	0	0	0	10 MS	6	tr R	0	0.2
		96/97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np			
	Mean														0.4	-	1.3								2.8			16.1
48	Condor 'S'	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	0	0	np	np	np	0	0	np	np	0	10 R	–	2.0
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	20 R-MR	4	0	0	np	20 MR	0	0	tr MR	1.5	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	10 R-MR	2	0	np	0	np	0	5 MS	np	1	0	0	0
		95/96	np	0	0	np	0	np	np	30 S	tr S	0	0	0	3.6	–	–	0	20 S	0	0	0	tr MS	5 MS	10.8	0	0	0
		96/97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.7	–	2.0								4.5			4.1

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																									
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
49	*Triticum boeoticum* No. 600674	92/93	0	tr S	np	np	np	np	np	np	30 S	10 S	0	0	7.0	40 S	40	np	np	np	0	0	np	np	0	0	–	0
		93/94	0	tr S	np	0	0	10 S	np	np	np	10 S	0	10 S	4.0	60 S	60	0	0	np	100 S	0	80 S	5 MR	30.0	tr R	–	0.4
		94/95	20 S	np	np	0	30 S	np	np	np	np	0	0	tr S	7.4	40 S	40	0	np	0	np	–		np	0	0	0	0
		95/96	np	tr S	0	0	0	np	np	80 S	0	10 S	0	0	10.2	–	np	tr MS	60 S	0	80 S	0	10 MS-S	0	21.4	0	0	0
		96/97	0	0	0	0	0	tr S	0	tr S	0	10 S	0	tr S	1.3	0	0	np	np	np	np	np	np	np	np	0	0	0
	Mean														7.2	–	22.8								12.9			0.1
50	*T. boeoticum* No. 600742	92/93	0	0	np	np	np	np	np	np	10 S	0	0	0	1.7	40 S	40	np	np	np	0	0	np	np	0	20 R	–	4
		93/94	0	0	np	0	0	10 S	np	np	np	10 S	0	0	2.5	40 S	40	50 S	np	np	100 S	20 S	80 S		75	tr R	–	0.4
		94/95	0	np	np	0	10 S	np	np	np	np	0	10 S	0	2.4	50 S	50	0	np	20 S	np	–		np	5	0	0	0
		95/96	np	0	0	np	0	np	np	30 S	0	0	0	0	6.7	–	–	0	50 S	0	60 S	0	5 MS	30 S	19.1	tr R	0	0.2
		96/97	0	0	0	0	0	tr S	0	0	30 S	0	0	tr S	2.8	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														3.3	–	26.0								24.8			0.9
51	*T. dicoccoides* No. 600363	92/93	0	0	np	np	np	np	np	np	0	0	0	0	0	30 S	30	np	np	np	np	np	np	np	0		–	–
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	60 S	60	np	np	np	80 S	np	np	np	20	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	40 S	40	0	np	20 S	np	–		np	10	0	0	0.0
		95/96	np	0	0	0	0	np	np	0	0	tr S	0	0	0.3	–	–	0	5 R	20 S	100 S	0	0	0	17.3	0	0	0.0
		96/97	0	0	0	0	0	tr S	0	0	20 S	0	0	0	1.8	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.4	–	26.0								4.9			0.1
52	*T. dicoccoides* No. 600375	92/93	0	0	np	np	np	np	np	np	np	np	np	np	0	40 S	40	np	np	np	0	0	np	np	0	–		–
		93/94	0	0	np	np	np	np	np	np	np	np	np	np	0	40 S	40	np	np	np	80 S	np	np	np	20	–	–	–
		94/95	0	np	np	0	0	np	np	np	np	0	np	np	0	40 S	40	0	np	20 S	np	–	–	np	5	–	–	–
		95/96	np	0	0	0	0	np	np	0	0	np	np	np	0	–		tr MS	0	30 S	0	0	0	0	4.5	–	–	–
		96/97	0	0	0	0	0	tr S	20 S	5 S	10 S	10 S	tr S	0	4.1	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.8	–	24.0								7.4			–

Appendix 2. (Cont'd)

No.	Cultivar/ Line / *Lr* or *Sr* gene	Season	Country/Site																								
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	New Halfa	CI	Adet	Alemaya	Ambo	Debre Zeit	Holetta	Kulumsa	Sinana	ACI	Dhamar	Seiyun	ACI
53	*Triticum dicoccoides* No. 600679	92/93	0	40 S	np	np	np	np	np	np	0	0	0	0	6.7	40 S	40	np	np	np	0	0	np	np	0	-		
		93/94	0	0	np	0	0	0	np	np	np	0	0	0	0	60 S	60	np	np	np	np	np	np	np	np	-	-	-
		94/95	0	np	np	tr S	10 S	np	np	np	np	0	0	0	1.7	80 S	80	0	np	20 S	np	-	-	np	5	-	-	-
		95/96	np	0	0	0	0	np	np	0	0	0	0	0	0	-		50 S	0	40 MS	0	0	0	60 S	20.3	-		
		96/97	0	0	0	0	0	0	0	0	tr S	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	-	-	-
	Mean														1.7	-	45.0								8.4			
54	*T. dicoccoides* No. 600715	92/93	np	np	np	np	np	np	np	np	0	np	np	np	0	40 S	40	-	-	np		-		np			-	-
		93/94	np	np	np	np	np	np	np	np	np	np	np	np	0	50 MS-S	40	np	np	np	np	np	np	np	np	-	-	-
		94/95	np	np	np	tr S	0	np	np	np	np	0	np	np	0	20 S	20	5 MS	np	20 S	np	-	-	np	6		-	-
		95/96	np	np	np	np	0	np	np	0	0	np	np	np	0	-		50 S	0	40 MS	0	0	0	60 S	18.9			-
		96/97	np	np	np	np	np	np	np	np	np	np	np	np	0	0	0	np	np	np	np	np	np	np	Np	-	-	-
	Mean														0.0	-	20.0								12.5			
55	El-Neilain	92/93			np	np	np	np	np	np	-	np	np	np	-	np	10	np	np	np	np	np	np	np	np	10 R	tr R	2.4
		93/94	-						-	-	-		-	-		40 MS-S	32	-		np	-	X		np	np		-	-
		94/95	np	np	np	10 MR	0	np	np	np	np	0	np	np	1.3	10 MR-MS	4	0	np	0	np	0	0	np	0		-	-
		95/96	np	np	np	np	0	np	np	tr S	0	np	np	np	0.7	-		0	80 S	50 S	0	0	tr MS	80 MS	27.9			
		96/97	0	0	0	np	0	0	np	0	0	np	np	np	0	np	0.4	np	np	np	np	np	np	np	np	-	-	
	Mean														0.4	-	9.3								13.9			0.5
56	Baladi	92/93	30 S	40 S	np	np	np	np	np	np	40 S	30 S	10 S	10 S	26.7	40 S	40	np	np	np	np	np	np	np	np	0		0
		93/94	10 S	60 S	np	10 S	40 S	40 S	np	np	np	10 S	0	0	21.7	np	32	np	np	np	np	np	np	np	np	tr R	0	0.2
		94/95	50 S	np	np	40 S	40 S	np	np	np	np	10 S	0	0	20.0	10 MR-MS	4	0	np	0	np	0	0	np	0	tr R	0	0.2
		95/96	np	40 S	20 S	10 S	30 S	np	np	10 S	tr S	10 S	0	0	13.5	-	-	0	5 MS	50 S	0	0	0	20 MR	8.9	tr R	0	0.2
		96/97	20 S	30 S	20 S	10 S	10 S	10 S	20 S	10 S	40 S	10 S	0	10 S	15.8	0	np	np	np	np	np	np	np	np	np	-	-	-
	Mean														19.5	-	12.2								4.5			0.1

X = mixed type of reaction.

Appendix 2. (Cont'd)

No.	Cultivar/ Line *Lr* or *Sr* gene	Season	Country/Site																									
			Egypt													Sudan‡		Ethiopia								Yemen		
			Nubaria	Ismailia	El-Serw	Zarzoura	Gemmeiza	Sakha	Kelein	Sidi-Salem	Sids	Shandaweel	Mataana	Kom Ombo	ACI	*New Halfa*	*CI*	*Adet*	*Alemaya*	*Ambo*	*Debre Zeit*	*Holetta*	*Kulumsa*	*Sinana*	ACI	Dhamar	Seiyun	ACI
57	Mokhtar	92/93	np	np	np	np	np	np	np	np	np	np	np	np	np	–	–	np	np	np	np	np	np	np	np		–	–
		93/94	np	np	np	np	np	np	np	np	np	np	np	np	np	50 MR-MS	40	np	np	np	np	np	np	np	np	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	30 MR-MS	12	0	np	5 S	np	0	0	np	1.1	tr R	0	0.4
		95/96	np	0	0	0	0	np	np	tr S	5 S	0	0	0	0.8		–	0	0	60 S	10 MR	0	5 MS	20 MS	12	tr R	0	0.2
		96/97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.3	–	13.0								1.1			0.1
58	Aziz	92/93	np	np	np	np	np	np	np	np	np	np	np	np	np	–	–	np	np	np	np	np	np	np	np	tr R		0.4
		93/94	np	np	np	np	np	np	np	np	np	np	np	np	np	40 MS-S	32	np	np	np	np	np	np	np	np	tr R	–	0.4
		94/95	0	np	np	0	0	np	np	np	np	0	0	0	0	10 R-MR	2	0	np	5 S	np	0	0	np	1.1	tr R	0	0.2
		95/96	np	0	0	0	0	np	np	0	0	0	0	0	0	–	–	0	5 R	60 S	0	0	tr MS	20 MS	11.2	0	0	0
		96/97	0	0	0	np	0	0	np	0	tr S	0	0	0	0.2	0	0	np	np	np	np	np	np	np	np	–	–	–
	Mean														0.1	–	8.5								6.7			0.2
59	Marib	92/93	np	np	np	np	np	np	np	np	np	np	np	np	np	–	np	np	np	np	np	np	np	np	np	tr R	–	0.2
		93/94	np	np	np	np	np	np	np	np	np	np	np	np	np	30 MS-S	24	np	np	np	np	np	np	np	np	tr R	–	0.2
		94/95	0	np	np	tr MS	0	np	np	np	np	0	np	np	0.1	5 R-MR	1	0	np	0	np	0	0	np	0	tr R	0	0.2
		95/96	np	0	0	0	0	np	np	30 S	0	0	0	0	3.3		np	0	15 S	20 S	0	0	tr MS	2 MS	12.6	0	0	0
		96/97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	np	np	np	np	np	np	np	np	–	–	
	Mean														1.1	–	6.3								6.3			0.2
60	Little Club	92/93	40 S	40 S	np	np	np	np	np	np	30 S	30 S	10 S	tr S	25.5	80 S	80	np	np	np	np	np	np	np	np	40 S	–	20
		93/94	60 S	40 S	np	40 S	30 S	30 S	np	np	np	30 S	10 S	10 S	31.3	100 S	100	np	np	np	40 S	10 S	np	np	25	40 S	–	20
		94/95	40 S	np	np	tr S	40 S	np	np	np	40 S	10 S	10 S	10 S	21.7	40 S	40	40 S	np	40 S	np	20 MS	20 MS	np	28.5	50 S	40 S	45
		95/96	np	60 S	60 S	40 S	30 S	np	np	10 S	30 S	10 S	10 S	10 S	28	–		50 S	40 S	60 S	100 S	10 MS	20 MS-S	20 S	42	10 S	80 S	45
		96/97	40 S	40 S	40 S	60 S	60 S	30 S	40 S	10 S	20 S	60 S	30 S	10 S	36.7	20 MS	16	np	np	np	np	np	np	np	np	0	0	0
	Mean														28.6	–	47.2								31.8			34.0

Appendix 3. Daily average number of leaf rust spores/m^3 of air at three sites in Egypt: Nubaria (Nub), Sids and Shandaweel (Sha), 1994–1997.

Month	1994			1995			1996			1997			Mean		
	Nub	Sids	Sha	Nub	Sids	Sha	Nub	Sids	Sha	Nub	Sids	Sha	Nub	Sids	Sha
Jan	15	4	18	3	3	0	3	3	0	1	4	0	6	4	5
Feb	28	0	5	6	4	22	3	2	13	(13)	3	12	13	2	13
Mar	128	36	98	13	8	6	5	3	8	26	11	6	43	15	30
Apr	95	33	75	22	0	11	21	5	16	50	22	4	47	15	27
May	102	54	18	17	6	8	(5)	6	0	20	26	11	36	23	9
Jun	50	50	33	15	6	11	(5)	22	(6)	50	8	20	30	22	18
Jul	31	20	(18)	5	21	5	(5)	0	(6)	9	6	12	13	12	10
Aug	13	21	(18)	5	5	3	10	(4)	12	7	6	7	9	9	10
Sep	4	7	(18)	3	2	5	6	7	6	–	–	–	4	4	10
Oct	12	4	2	3	1	5	10	1	13	–	–	–	8	2	7
Nov	3	(2)	0	1	0	0	2	2	1	–	–	–	2	1	1
Dec	2	0	0	3	0	0	6	10	3	–	–	–	4	3	1

( ) missing data averaged from preceding and following months.

Appendix 4. Daily average number of leaf rust spores/m^3 of air at three sites in Ethiopia: Holetta (Hol), Debre Zeit (Dez) and Kulumsa (Kul), 1993–1997.

Month	1993			1994			1995			1996			1997			Mean		
	Hol	Dez	Kul	Hol	Dez	Kul	Hol	Dez	Kul	Hol	Dez	Kul	Hol	Dez	Kul	Hol	Dez	Kul
Jan	1	1	1	1	1	1	43	28	4	1	2	3	13	92	3	12	25	2
Feb	2	1	1	1	0	1	23	65	1	20	1	1	12	55	1	12	24	1
Mar	1	0	1	1	0	1	9	67	16	3	3	1	6	28	1	4	20	4
Apr	1	1	1	1	0	1	5	111	4	16	7	1	8	51	1	6	34	2
May	5	1	1	1	0	1	2	20	5	8	5	5	15	84	4	6	22	3
Jun	2	0	1	1	(0)	1	5	1	3	3	1	1	2	41	1	3	9	1
Jul	1	0	1	1	0	1	15	14	4	10	1	3	12	8	4	8	5	3
Aug	1	1	1	1	1	1	1	40	8	11	16	2	7	7	9	4	13	4
Sep	1	1	2	1	1	1	18	6	17	23	11	1	–	–	–	11	5	5
Oct	1	1	16	1	1	1	47	6	28	63	88	1	–	–	–	28	24	12
Nov	1	0	6	1	5	1	36	4	19	22	294	5	–	–	–	15	76	8
Dec	1	0	1	10	1	1	29	5	7	38	161	5	–	–	–	20	42	4

( ) missing data averaged from preceding and following months.

Appendix 5. Daily average number of leaf rust spores/m^3 of air at New Halfa in Sudan, 1993–1997.

Month	1993	1994	1995	1996	1997	Mean
Jan	8	(8)	0	0	4	4
Feb	4	(8)	1	0	28	8
Mar	2	16	1	0	13	6
Apr	1	1	2	(0)	4	2
May	(1)	0	2	0	8	2
June	(1)	0	(1)	1	–	1
July	(1)	0	(1)	7	–	2
Aug	0	0	0	14	–	4
Sept	0	0	0	8	–	2
Oct	(1)	1	0	5	–	2
Nov	(1)	2	0	42	–	11
Dec	(1)	2	0	33	–	9

( ) missing data averaged from preceding and following months.

Appendix 6. Daily average number of stem rust spores/m^3 of air at three sites in Egypt: Nubaria (Nub), Sids and Shandaweel (Sha), 1994–1997.

Month	1994			1995			1996			1997			Mean		
	Nub	Sids	Sha	Nub	Sids	Sha	Nub	Sids	Sha	Nub	Sids	Sha	Nub	Sids	Sha
Jan	8	1	8	3	1	0	4	6	0	10	6	0	6	4	2
Feb	17	10	11	3	4	3	6	2	20	16	27	1	11	11	9
Mar	85	17	50	51	9	5	4	5	6	64	49	0	51	20	15
Apr	68	17	62	33	4	3	28	3	3	35	20	9	41	11	19
May	81	10	8	16	1	0	10	7	0	27	35	35	34	13	11
Jun	21	10	9	3	5	6	(7)	0	(3)	30	6	6	15	5	6
Jul	35	12	(7)	2	17	0	(7)	0	(3)	10	10	4	14	10	4
Aug	6	8	(7)	1	0	0	3	(3)	6	11	3	7	5	5	5
Sep	1	2	(7)	5	1	1	1	7	6	–	–	–	2	3	5
Oct	7	2	7	3	1	0	1	2	4	–	–	–	4	2	4
Nov	2	(1)	5	1	0	0	3	2	1	–	–	–	2	1	2
Dec	0	0	8	2	0	0	1	1	2	–	–	–	1	1	3

( ) missing data averaged from preceding and following months.

Appendix 7. Daily average number of stem rust spores/m^3 air at three sites in Ethiopia: Holetta (Hol), Debre Zeit (Dez) and Kulumsa (Kul), 1993–1997.

Month	1993			1994			1995			1996			1997			Mean		
	Hol	Dez	Kul	Hol	Dez	Kul	Hol	Dez	Kul	Hol	Dez	Kul	Hol	Dez	Kul	Hol	Dez	Kul
Jan	2	1	0	1	0	1	7	24	4	1	1	3	10	53	2	4	16	2
Feb	1	1	28	1	0	1	10	103	1	6	0	1	5	20	1	5	25	6
Mar	1	0	0	0	0	1	2	141	5	3	5	1	4	15	1	2	32	2
Apr	1	0	1	1	1	1	1	316	4	14	8	9	8	26	6	5	70	4
May	1	1	1	1	0	1	1	38	7	3	3	6	6	33	2	2	15	3
Jun	1	0	1	0	(0)	0	1	5	2	3	1	2	1	36	2	1	8	1
Jul	1	1	1	1	0	1	10	9	4	2	1	5	9	14	5	5	5	3
Aug	1	1	0	1	1	0	1	35	3	3	13	5	4	10	8	2	12	3
Sep	1	1	1	1	1	1	7	6	16	7	10	7	–	–	–	4	5	6
Oct	1	1	12	3	1	2	20	2	18	46	144	8	–	–	–	18	37	10
Nov	1	0	8	1	3	1	16	3	18	18	289	5	–	–	–	9	74	8
Dec	1	0	1	3	21	1	13	0	9	18	141	6	–	–	–	9	41	4

( ) missing data averaged from preceding and following months.

Appendix 8. Daily average number of stem rust spores/m^3 of air at New Halfa in Sudan, 1993–1997.

Month	1993	1994	1995	1996	1997	Mean
Jan	4	(57)	4	0	41	21
Feb	4	(57)	6	0	30	19
Mar	2	112	7	0	68	38
Apr	2	46	14	1	38	20
May	(2)	4	12	1	27	9
Jun	(2)	3	(6)	1	–	3
Jul	(2)	2	(6)	(19)	–	7
Aug	0	0	0	38	–	10
Sep	0	0	0	0	–	0
Oct	2	4	0	9	–	4
Nov	1	4	0	38	–	11
Dec	3	3	0	78	–	21

( ) missing data averaged from preceding and following months.