**Tanta University**
Faculty of Agriculture
Agricultural Botany Department

# STUDIES ON STEM RUST DISEASE OF WHEAT

*By*

**Atef Abd El-Fattah Mohamed El-Sayed**

B. Sc. (Plant Pathology), 1989

Faculty of Agriculture, Tanta University

**Thesis**

Submitted in Partial Fulfillment for the Requirements for the

Degree of Master

In

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**Approved by :**

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# Contents

## Introduction

Wheat (*Triticum aestevum* L.) is considered to be one of the most important food crops allover the world. It supplied1/5 of the food energy to the human being worldwide.

In Egypt the local consumption exceeds the production by *ca* 30 %. consequently the government did its best affords to fill the gap between consumption and production by both vertical and horizontal extension via increasing the productivity of acreage unit through the genetic improvement to the maximization of production (high yielding varieties) and controlling disease, insects and weeds on one hand, on the other hand, by increasing the area grown with wheat by addition of new cultural area through soil reclamation and the reassortment of crop structure trough the strategic cultural policy.

We can not deny, that wheat rusts are the limiting factor of wheat mass production. So, production of profitable, high yielding and rust resistant varities is the ultimate objectives for any wheat breeder, pathologist and producer allover the world.

From this stand point the present work has been issued to contribute solutions for stem rust disease as a problem.

One of the disease problem is the dynamic nature of the rust pathogen. This topic was studied through certain items i.e. race identification through classic and recent systems, distinction efficacy of races virulant and resistant genes, identification of resistant genes within certain commercials varieties.

Another topic included in this study is "The partial resistance" since this subject was dealt through studying it's components, relation of the anatomical structure with disease resistance, and effect of rust disease on wheat root-system.

In addition, certain wheat entries were evaluated against stem rust disease and genetic studies for slow rusting under field condition were conducted.

I hope to add little for solving the rust problem in Egypt through the present work..

# Review of Literature

**Race identification:**

The term physiological specialization refers to the occurrence of entities within morphologic characters of the living organism. In the fungi, such entities have been designated variously as physiologic strains, physiologic forms, biologic forms and races. These terms were used for a long time more or less synonymously until "physiologic race" was officially adopted and became generally accepted as standard **(Fischer & Holton, 1957).** On the other hand, **Holton, *et al.*, (1968)** reported that pathogenic specialization is the reflection of the interaction between virulent genes of the parasite and resistant genes of the host.

The problem of change in genetic constitutions in both hosts and parasites in rust fungi is considered to be the main obsticle of increasing wheat mass production in Egypt and in most of the worldwide countries. Therefore, one of the contributions adopted for solving such a problem was accomplished through the identification of physiologic races and recording their virulence.

**In Egypt**, the first reports on physiologic specialization of wheat stem rust incited by *Puccinia graminis tritici* was carried out in 1949 **(Abdel-Hak, 1953)**, who identified 15 physiologic races at different locations in Egypt *i.e.* 9, 11, 14, 17, 19, 21, 24, 42, 53, 59, 69, 88, 123, 279 (E2) and (E1). Later on **(Abdel-Hak and Kamel, 1966)** so far, recorded races *i.e.* 117, 133, 186, 194 and 249 in Egypt.

**Kamel, (1964)** identified subrace 24A (Egypt) which was differentiated from race 24 in it's ability to produce type 2 of reaction on Kota while race 24 produces type 0. Also, he succeeded

to identify 3 subraces from race 17 namely: 17A (Egypt), 17B (Egypt) and 17C (Egypt) on the basis of their reaction on 3 supplementary differentials.

**Abdel-Hak, *et al.* (1973)** identified race 15B for the first time in Egypt and Pakistan during 1970/71.

**Abdel-Hak, *et al.* (1975)** added races i.e. 14, 17, 19, 24, 42, 21, 133, 186, 194, 9, 11, 53, 122, 243, 15, 34 and 117 most of them, however, were previously identified.

**Abdel Hak, *et al.*, (1982)** designated 19 physiologic races during 1976–1980. Race 11 was the predominant one followed by races *i.e.* 11B, 15B, 15 and 34. So far they identified races 10, 18, 49, 83, 176, 189 and 274 as virulent races having new virulences.

**Abu El-Naga, *et al.*, (1990)** identified 8 physiologic races of *P. graminis tritici* during 1987/88. Again race 11 was the predominant one, followed by races 34, 17, 11B, 19, 24, 15 and 98. However, eleven races namely 11B, 11, 34, 24, 293, 15B, 17, 20, 21, 200 and 278 were identified during 1988/89. Races 293, 268, and 278 so far, were isolated in Egypt.

**El-Daoudi, *et al.*, (1992)** revealed presence of 7 and 6 physiologic races of *P. graminis tritici* the causal agent of wheat stem rust, viz: 11, 34, 17, 14, 24, 39 and 285, 11, 11B, 15, 17, 24 and 34 during 1989/90 and 1990/91, respectively. They gave evidence to predominance of races 11, 34, 24 and 17 in relation to the other ones. **Abu El-Naga, *et al.*, (1993)** revealed existence of five physiologic races of *P. graminis tritici* in Egypt during 1991/1992.

**El-Sherif, *et al.* (1996)** identified five physiologic races of *P. graminis tritici i.e.* 11, 15, 17, 19 and 39. Race no. 11 was the most predominant, however race 39 was the most virulent one followed by 19, 17, 11 and 15.

**Mohamed (2001)** identified 5 physiological races in Egypt during 1994/1995 *i.e.* race 11, 17, 15, 19 and 39 while, during 1195/1996 races 11, 19, 17, 39 and 15 were identified. The first common race was no. 11. On the other hand, 40 and 65 virulence formulae were drived from 88 and 68 single pustules, during 1994/95 and 1995/96, respectively.

As regard to the physiologic races of *Puccinia graminis tritici.* Identified in countries other than Egypt, an extensive task was done in this regard for example:

**Watson (1970)** reported that virulence has come to be recognized as character controlled by a group of specific genes which may be influenced by those controlling pathogenicity.

**Roelfs (1971)** stated that race 15 of *Puccinia graminis tritici* represented 63% of the 2048 isolates in co-operative rust laboratory during 1970. It was predominant in most areas. Also, race 15B-2 was the most prevalent of that race group added to race 151 which represented 20% of the isolates, these races were predominated in United States

**Roelfs and Mc Vey (1972)** confirmed that 38% of stem rust isolates collected from the Northern great plains were designated as race 15B-2. They found later on (1974) that race 15-TMN (5%) and -TLM (14%), race 151-QFB (13%), -QSH (8%), -QCB (2%). In (1975) they added other race and race groups during the season *i.e.* 15 (-TDM, 2% and –TBM, 1%), 151 (-QCC, 2%); 56 (-MBC, 3%) and

race group 11-32-113 (-RKQ 2%, -RTQ and –RPI% each); and race 17 (-HDL 1% and -HNL 2%). Later on, they found (1976) that race TNM was the most prevalent one during the period (1972-1976).

**Bartos *et al.* (1982)** Stated that 19 physiological races were recognized among isolates collected in Czechoslovakia between 1977 and 1980. Races 11 and 34 were the commonest.

**Baghadadi (1984)** found that 7 different races were distinguished in the Khashm El-Girbia district during 1970-1974. The most prevalent race was no. 21, while races 222, 34, 186 and 194 were identified for the first time in Sudan.

**Dmitriev (1984)** found that 10 races of stem rust (*P. graminis* f. sp. *tritici*) were recorded on wheat. Race 53 was predominated in Ethiopia.

**Martens and Dunsmore (1988)** designated 6 new virulence formulae in Western Canada. Race C53 (15 TNM) was the most predominant one during 1977. *Sr*'s: 46, 22, 24, 26, 27, 29, 30 and 37 proved their efficacy as resistant genes in Canada.

**Roelfs and Martens (1988)** used a new set of international differential hosts for characterizing the virulence of cultures of *Puccinia graminis* f. sp. *tritici* including the host resistance genes *i.e. Sr*'s: 5, 6, 7b, 8a, 9b, 9e, 9g, 11,17,21,30 and 36. Races were designated by a three-letter Code (Pgt-Code) followed by a hyphen and a listing of those host genes in the resistant set on which the race was virulent.

**Martens *et al.* (1989)** identified 10 virulence combinations (Pgt-code races) from 301 isolates. Races QCC (-C 95, C 96) was predominant in British Columbia virulence was not detected to

resistance genes *i.e. Sr*'s: 13, 22, 24, 25, 26, 27, 29, 30, 31, 32, or 37 to any of spring wheat cultivars recommended for the prairie region.

**Roelfs *et al.* (1989)** confirmed the predominance of race 15 TNM on wheat having *Sr* 17. *Sr*'s: 13, 22, 24, 25, 26, 27, 29, 31, 32, 33, 37, $Gt^{+}$ and WLD-1 reported their efficacy as resistance genes in USA.

**Roux (1989)** identified 7 pathotypes of *P. graminis tritici* in Southern Africa, out of them 2SA 4 was predominant and virulent to *Sr* 9e followed by pathotype 2SA100 which was virulent to *Sr* 24. The rest of pathotypes were: 2SA32, 2SA101, 2SA43, 2SA6 and 2SA2.

**Harder and Dunsmore (1990)** Observed that race TMP continued to predominant in eastern Canada, but continued to decline in the prairie regions. Race QFC became the most common race in the prairies other races isolated were QCL, RCC, RCR and SPM.

**Hu and Roelfs (1990)** found that race HKR (21C3) was the most common virulence combination making up 33.1% of the 127 isolates from 70 collections. The second most common race PKR (34C2), which made up 24.4% of isolates.

**Harder and Dunsmore (1993)** reported that four races were identified from 514 isolates of *Puccinia graminis tritici* obtained from wheat, cultivated barley and wild barley from Ontario and Quebec, races TPM (51.6%), QFC (35.5%) and QCC (12.9%), from Manitoba and Saskatchewan, races QCC (33.5%), TPM (32.6%), QFC (26.4%) and RCR (7.4%). All isolates from all sources were virulent to genes *i.e Sr*'s: 5, 21, 9g and 17. No

virulence was detected to resistance genes *i.e. Sr*'s: 6, 13, 22, 24, 25, 26, 27, 29, 30, 31, 32 or 37.

**Bartos *et al.* (1994)** distinguished two pathotypes *i.e.* 34 and 11 in Czech and Slovak Republics during 1991 and 1992. Registered varieties *i.e.* Torysa and Bruta showed moderate reaction to both races. On the other hand, varieties with the gene *Sr* 31 associated with the 1BL/1Rs translocation showed high resistance. Resistance was being higher at seedling than at maturity.

**Harder, *et al.* (1994)** reported that an additional subset of differential genes (*Sr* 9a, *Sr* 9d, *Sr* 10, *Sr* Tmp) for *Puccinia graminis* f. sp. *tritici* was added in 1993. Thus races were identified with a 4-letter code. Pathotype TPMK was most frequently isolated from wheat followed by QFCS, QCCJ, RCRS, QFCJ, RKQQ and RKRQ. These pathotypes were virulent to genes *Sr* 5, *Sr* 21, *Sr* 9d and *Sr* 19. On the other hand, the pathotypes were avirulent to genes *Sr* 13, *Sr* 22, *Sr* 24, *Sr* 25, *Sr* 26, *Sr* 27, *Sr* 29, *Sr* 30, *Sr* 32 and *Sr* 37.

**Manninger (1994)** pointed out the main races in the *Puccinia graminis* f. sp. *tritici* population, identified by the Stakman method, were races 1, 11, 34 and 218. Races 17, 21 and 126 were at trace levels in the population. The *P. graminis* f. sp. *tritici* population was stable during 1989-91 and no new races were found. A total of 24 pathotypes were identified from all *P. graminis* f. sp. *tritici* races in the survey by testing against 23 isogenic wheat lines in Hungary.

**Lekomtseva *et al.* (1994)** identified 4 physiological races. Races 40, 34, 11 (identified only on barberry) and 166 were studied

using 50 fungal isolates obtained from naturally infected wheat and barberry plants in the Moscow region, Russia, in 1992.

**Yao-Ping *et al.* (1995)** found that the new physiological race 21C3CTR, virulent to wheat with the stem rust resistance gene *Sr* 11, was found in Sichuan province (Leshan city), China, in 1993.

**Mc Vey *et al.* (1997)** found that races Pgt-TPMK and QCCJ made up 39 and 31 % of all isolates, respectively. Race TPMK comprised 67% of isolates from farm field. No virulence was found to wheat lines with genes *i.e Sr*'s: 6, 9b, 13, 22, 24, 25, 26, 27, 29, 30, 31, 32, 33, 37, Gt+ or Wdl-1 in USA.

**Harder (1999)** gave evidence to the presence of 24 pathotypes of *P. graminis tritici* in Canada. Pathotype TPMKR was the predominant one during two successive seasons *i.e.* 1996/97 and 1997/98 followed by pathotypes QCCJD and QFCSR, RCCJN and QCCJN. These pathotypes were virulent to *Sr*'s: 5, 21, 9g and 9d and were avirulent to *Sr*'s: 22, 24, 25, 26, 27, 29, 30, 31, 32, 33, 35, 37 and 40.

**Mc Vey *et al.* (1999)** identified two physiologic races of *Puccinia graminis tritici* in U.S.A viz: TPMK and QFCS with a frequency of 66% and 26%, respectively. No virulence was found to *Sr* genes *i.e.* 9b, 13, 22, 24, 25, 26, 27, 29, 30, 31, 32, 37, $Gt^{+}$ or WLD-1.

**Effectiveness of wheat stem rust monogenic lines (*Sr*'s):**

**Corazza (1986)** confirmed the effectiveness of *Sr* 21 and *Sr* 22 derived from *Tritium monococcum* and *T. dicoccum* (Vernal and Khapli) against stem rust population in Italy. *Sr* 11 proved it's effectiveness against 50% of the tested isolates.

**Roelfs *et al.* (1987)** indicated that race 15-TMN was dominant in USA during 1987, this race was virulent to *Sr* 17. They concluded that *Sr*'s: 13, 22, 24, 25, 26, 27, 29, 31, 32, 33, 37, $Gt^+$ and Wld-1 are considered to be resistant genes for stem rust in USA and Mexico during 1986/1987.

**Hu (1988)** stated that gene *Sr* 5, *Sr* 6, *Sr* 8a, *Sr* 11, *Sr* 17, *Sr* 36 and *Sr* TMP as resistant to stem rust in 36 Chinese cultivars following inoculation with 23 isolates of *Puccinia graminis*.

**Knott and Weller (1988)** found that the cv. K253 carried dominant gene (probably *Sr* 9e) for resistance to races 29 and 56 of *Puccinia graminis* f. sp. *tritici*, and a recessive gene for moderate resistance to race 15BL, when K253 was crossed with susceptible var. Marquis in Canada.

**Martens and Dunsmore (1988)** found that testing of 308 isolates of *P. graminis tritici*, 13 virulent combinations, including 6 new ones from western Canada, were identified. No virulence was identified on wheat lines with resistance genes *Sr* 46, *Sr* 22, *Sr* 24, *Sr* 26, *Sr* 27, *Sr* 29, *Sr* 30 and *Sr* 37 or on the spring wheat cultivars recommended for the eastern prairies.

**Bahadur (1989)** pointed out that seedling of 17 lines carrying *Sr*'s: 24, 25, 26, and 27 conferred resistance to stem rust. These lines were evaluated against 20 isolate genotypes. It was concluded that genetic background of isolates affected the expression of resistance genes.

**Casulli and Ruci (1991)** indicated that genes *Sr* 9b, *Sr* 26 and *Sr* 36 were the most effective ones followed by *Sr* 9e, *Sr* 11, *Sr* $Gt^+$, *Sr* 31 and *Sr* 32 for stem rust resistance. Durum wheat cultivars were highly resistant to all *P. graminis* isolates in Italy.

**Casulli and Pasquini (1993)** indicated that *Sr* 9e, *Sr* 11, *Sr* 13, *Sr* 31 and *Sr* 37 were the most effective resistance genes towards *P. graminis* at the seedling stage and *Sr* 11, *Sr* 13, *Sr* 25, *Sr* 26, *Sr* 32 and *Sr* 36 were effective at adult stage in certain durum and bread Italian wheat varieties.

**Harder *et al.* (1994)** stated that *Sr* 13, *Sr* 22, *Sr* 24, *Sr* 25, *Sr* 26, *Sr* 27, *Sr* 29, *Sr* 30, *Sr* 32 and *Sr* 37 were avirulent to all tested isolates of stem rust pathogen in eastern Canada.

**Manninger (1994)** reported that *Sr* 22, *Sr* 24, *Sr* 31, *Sr* 32, *Sr* 33 and *Sr* 36 were effective against all isolates collected from the survey, It was concluded that *Sr* 31 and *Sr* 36 were the most important resistant genes for Hungarian wheat varieties.

**Dyck and Sykes (1995)** screened common and durum wheat populations with Ethiopian origin for resistance to stem rust. They attributed the resistance to certain combinations of *Sr* 6, *Sr* 8a, *Sr* 9a, *Sr* 9d, *Sr* 9e, *Sr* 11, *Sr* 10, *Sr* 30 and *Sr* 36. One of the selections exhibited resistance based on the linkage between *Lr* 19/*Sr* 25 for both leaf and stem rusts.

**Stojanovic *et al.* (1995)** indicated that *Sr* 32 and *Sr* 33 showed high effectiveness against different pathotypes of stem rust (*Puccinia graminis*) in the wheat at seedling stage. However, at the adult plant stage, the lines with such genes were moderate resistant to highly susceptible in Yugoslavia.

**Chen *et al.* (1997)** found that testing of 10 isolates of *P. graminis* f. sp. *tritici* for avirulence/virulence gene combinations, 16 *Sr* genes (*Sr* 5, *Sr* 6, *Sr* 8a, *Sr* 9e, *Sr* 13, *Sr* 19, *Sr* 23, *Sr* 24, *Sr* 26, *Sr* 30, *Sr* 31, *Sr* 32, *Sr* 33, *Sr* 35, *Sr* 36 and *Sr* 38) out of the 49 tested were postulated as present in 75 wheat genotypes.

**Manninger *et al.* (1998)** showed that genes *Sr*'s, *Sr* 31 and *Sr* 36 were important genes for wheat stem rust resistance caused by *Puccinia graminis* in Hungary.

**Sawhney (1998)** stated that a number of wheat cultivars both from Indian and International programmes and certain near-isogenic lines, some of these sources, carrying genes *Lr* 34/*Yr* 18, *Sr* 2, *Sr* 26 and *Sr*31 that are recognized or conferring durable resistance to *Puccinia* spp.

**Reddy and Viswanathan (1999)** indicated that (*Lr* 19, *Lr* 24, *Lr* 26, *Lr* 28, *Sr* 25, *Sr* 26, *Sr* 27, *Sr* 31, *Yr* 9) were resistant to various rusts (*Puccinia*) in two Indian wheat backgrounds (HD2009, HD2380) when evaluated for grain yield performance under rust-free conditions. Lines carrying the rust resistance gene complex *Sr*31+*Lr*26+*Yr*9 from Veery 'S' gene exhibited the highest yield within the genetic backgrounds of both Indian wheat cultivars.

**Pretorius *et al.* (2000)** found that *Sr* 31 was resistant to various wheat and triticale cultivars in a nursery in Uganda.

**Seah *et al.* (2000)** indicated that (*Sr* 38, *Yr* 17 and *Lr* 37) conferred resistance to stem rust, stripe rust and leaf rust when introgressed within Australian wheat.

**Probable genes for stem rust resistance:**

**Loegering (1972)** indicated that the infection type is the phenotype expression of the interaction between corresponding gene pairs in a specific host-parasite interaction. A low infection type results form the interaction between alleles for low pathogenicity in the parasite and alleles for low reaction in the host, from the interaction between an avirulent pathotype and a resistant host.

**Sawhney *et al.*, (1982)** reported that lines carrying *Sr* 24, *Sr* 26, *Sr* 27, *Sr* 31, *Sr* 32, (*Sr*$T_{t+1}$ + *Sr* 9e) and (*Sr* $T_{t+1}$ + *Sr* 9b) were resistant. Also, The low coefficients of infections produced on Marquis *Sr* 12 and Spica (*Sr* 7b, *Sr* 17) suggest that the resistance in these lines may be due either to interactions with known factors or to additional unknown factors.

**Claude *et al.* (1986)** reported that 15 out of 391 spring wheat entries exhibited *Sr* 30, while V289 and V579 had genes *Sr* 13 and *Sr* 15, respectively, other genes for resistance to stem rust were not detected.

**Hu and Roelfs (1986)** found that Dong-Xie 3 and Dong-Xie 4 posses the genes *Sr* 5 and *Sr* 31. Feng-Kang 2, Feng-Kang 8, Jing-Dan 106, Yi 78-4078, Lu-Mai 1 and Yan 7770-4 probably have *Sr* 31. Feng-Kang 13 has *Sr* 5 plus another unidentified gene. Fu 63 Jing-Mai 11, Yan-An 15 and Bei-Nong 3217 probably has an undesignated resistant gene (s) effective against only few cultures.

**Singh and McIntosh (1986)** pointed out that genes associated with seedling resistance in Kenya Plume were *Sr*'s: 5, 6, 7a, 8a, 9b, 12 and 17. The predominant pathogen strains (*P. graminis tritici*) were avirulent to seedlings with *Sr* 7a, but exhibited virulence for the other genes. *Sr* 7a, however did not confer adult plant resistance when presented alone. Adult plant resistance was attributed to *Sr* 2 and possibly to the interaction of *Sr* 7a and *Sr* 12.

**Hu (1988)** indicated that resistant genes *i.e Sr* 5, *Sr* 6, *Sr* 8a, *Sr* 11, *Sr* 17, *Sr* 36 and *Sr* TMP were present in 36 Chinese cultivars inoculated with 23 isolates of *P. graminis*.

**Mc Vey (1990)** confirmed presence of *Sr*'s: 9e, 9f, 18, LC and McN in 578 spring spelt accessions in USDA through the conventional genetic studies using near–isogenic lines. Other genes for resistance postulated to be present, included *Sr*'s: 9a, 9d, 10, 15, 17, 19 and 20.

**Mc Vey (1992)** pointed out that five genes most commonly postulated in cultivars of wheat (*T. aestivum*) of the International Winter Wheat Performance Nursery XII to XVII, are designated as: *Sr*'s 5, Mc N, 17, 31 and 10. On the other hand, high virulence was recorded on *Sr*'s: 7b, 9d, 9e, 12, 13, 14, 15, 16, 25, 26 and 27.

**Riede *et al.* (1995)** found that 6 lines out of 12 proved to carry different single genes for resistance from "Waldron". A seventh line probably have 2 genes for resistance are one in common with WDR-C1 and WDR–C2. The gene in the WDR-E group is probably the same as this in *Sr*. WLD1, and that in WDR-F1 was the same as that of *Sr* 11.

**Imbaby *et al.*, (1997)** Studied ten new Egyptian wheat varities and 19 monogenic lines to determine the presence of resistance genes against 65 Isolates of stem rust *P. graminis* f. sp. *tritici*. Resistance genes were undetected in Sids-4, while *Sr* 9g was found in Sids-3 and *Sr* 9b and *Sr* 21 in Sids-9. Four genes were probably present in Sids-6 and Sids-7. Resistance genes with the highest frequency were *Sr* 9g, *Sr* 9b, 25 and *Sr* 36, while *Sr* 's: 5, 9e, 24, 26, 29 and $Gt^{+}$ were not detected and may be absent in the used Egyptian wheat varieties.

**Bai *et al.* (1998)** tested 49 accessions of *Triticum monococcum* to stem rust in Canada. They found that 2 out of them

were resistant to 2 isolates of *P. g. tritici i.e.* TM65 and TM257 and exhibited *Sr* 22 and *Sr* 35 in respect.

**Liu and Kolmer (1998)** evaluated certain Canadian wheat cvs. and found that Pasqua may have 3 genes conditioned field resistance and had seedling resistance genes: *Sr* 5, *Sr* 6, *Sr* 7a, and *Sr* 12. On the other hand, field resistance in Ac Taber was conditioned by *Sr* 2 it may have *Sr*'s 9b, *Sr* 11 and *Sr* 12 as seedling resistance genes.

**Manninger *et al.* (1998)** indicated that, entries *i.e.* GK Kincso, GK Gobe, GK Zomabor and Csornoc probably have stem rust resistance genes *Sr* 31, and *Sr* 36. However *Sr* 5 may be included in genotypes *i.e* GK Istvan, GK Barna, Yubileynaya 50, GK Delibab, GK Othalom, GK Csaba and GK Gerebin.

**Reddy and Viswanathan (1999)** evaluated 2 Indian wheat background (HD 2009 and HD2380) for grain yield performance under rust-free conditions. The stem rust (*P. graminis*) resistant gene *Sr* 27 gave significantly lower yield comparing to the chemically treated control with Tilt 0.5%. While, lines carrying the rust resistance gene complex *Sr*31+*Lr*26+*Yr*9 from Veery "S" gave the highest yield in the genetic background of both Indian wheat cultivars.

**Components of partial resistance in certain local wheat entries:**

**Van der plank (1963)** reported that the plant breeders have become interested in horizontal resistance, which is quantitative rather than qualitative. Horizontal resistance is characterized by one or more of the following: long latent period, few spore production, decreased infectious period little infection efficiency and small lesion size.

**Hooker (1967)** found that a long incubation time, small uredia and reduction in sporulation all of these factors may be resulted in slower rust development on certain wheat varieties. Also, all may be considered components of slow-rusting resistance.

**Ohm and Shaner (1976)** pointed out three stages of pathogenesis: latent period, pustule size and number of pustules per square centimeter of leaf area. They found that the latent period in two slow rusting varities was longer than in two fast-rusting ones. Also, they demonstrated that pustule size was largest on the leaves of fast-rusting varities than in the leaves of slow-rusting ones, which was more restricted. They added that fewer pustules per square centimeter of leaf were found in the slow rusting varities.

**Samborski *et al.* (1977)** concluded that the colony size of *Puccinia graminis* f. sp. *tritici* in genotypically resistant leaves of wheat varities, seemed to be smaller than those in genotypically susceptible leaves at all temperature tested.

**Parlevleit (1978)** explained partial resistance (slow-rusting resistance) by a reduction in infection frequency, shorter infection period and longer latent period.

**Kapoor and Joshi (1981)** tested 6 wheat entries against race 122 of *P. graminis tritici*. They found that "Sonalika" was characterized by producing fewer flecks and pustules/cm$^2$ than those produced in the rest. Also they found that "Kharchia" and "Agrolocal" exceeded "Sonalika" by 1-2 day longer in latent period.

**Shaner (1983)** pointed out that slow-rusting wheat cultivars characterized by fewer uridiniospores produced per uridium as compared to those produced in fast rusting ones.

**El-Daoudi *et al.* (1985)** tested 4 Egyptian wheat varities *i.e.* Giza 157, Sakha 61, Sakha 62 and Sakha 69 against two races of *P. graminis tritici* differed in their virulences. The varities were significantly different in their reactions, number of pustules/cm$^2$, latent period, and area under disease progress curve. The tested varities exhibited good levels of incomplete resistance and they were able to slow down the rust development.

**Kapoor and Joshi (1986)** proved that components of slow rusting of stem rust i.e. lower pustule density, small pustule size, longer latent period and reduced spore production, were best combined in cv. "Sonalika", however the reverse was true with the cv. "Agra". Heritability estimates were fairly high for pustule size and latent period, lower for pustule density and moderately high for the amount of spore production.

**Ragab *et al.* (1989)** tested 8 Egyptian of wheat cultivars against two physiologic races i.e. 11 and 34 of stem rust different in their virulences. The cultivars were classified into two groups: The first included Sakha 69, Sakha 61, Sakha 92, Giza 162 and Baart which exhibited a good level of incomplete resistance, whereas they were able to slow down the rust development, the second included cvs. *i.e.* Sakha 8 and Giza 157 which exhibited shorter latent period, more uredia per square centimeter of leaf surface.

**Histological studies:**

Morphological resistance to *P. graminis* is dependent on the structure of the plant rather than on the host parasite inter relationship. The pathogen can complete the infection process and develop normally in a variety with physiologic susceptibility, but the structure characters of the host may be such as to prevent an

extensive development of the rust fungus. *P. graminis tritici* development which is possible only in the chlorophyll non-lignified tissues. In the stem the rust can grow only in the chlorophyllous collenchyma bundles, which extend lengthwise of the stem and are partly surrounded by the thick walled, sclerenchyma.

In the past, morphological resistance to plant diseases in general and to rusts in particular was extensively studied. In this respect **Cobb (1892)** advanced a "mechanical theory" to explain rust resistance, assuming that morphological characters, such as thick cuticle, waxy covering, small stomata, large number of leaf hairs, or upright leaves, might be responsible for the resistance of certain varieties.

**Hitchcock and Carleton (1893)** found that wheat varieties with thick epidermis and many hairs were less likely to be attacked by rust pathogens than otherwise plant.

**Ward (1902)** studied size, number and distribution of the stomata, the vascular bundles, the chlorophyll containing tissues and the sclerenchyma tissue of the broom leaves infected with *P. dispersa*. He then reported that, resistance to this pathogen was not accounted by observable structural peculiarities, but it was due to internal or intraprotoplastic properties beyond the scope of the microscope.

**Hurch (1924)** investigated the possibilities of morphological basis to rust resistance, he found that the stems of some resistant wheat varities contained large amount of sclerenchyma constituting a mechanical barriers against the spread of mycelium and limiting the size of the pustules. On the other hand, the susceptible varities were characterized by extensive

strands of collenchyma and little sclerenchyma and were showing broad and confluent pustules. He also pointed out that, the distribution of sclerenchyma and collenchyma in wheat culms were correlated with rust disease resistance.

**Hart (1931)** found that the size, shape and distribution of collenclyma strands in the peduncle are important factors in determining the spread of the mycelium and the size of rust pustules. Also, she reported that there is a positive correlation between rust reaction and the proportion of collenchyma in the peduncle. Wheat varities are susceptible when they have large proportions of collenchyma in their peduncles, whereas the resistant varities have less collenchyma in their stems. She added that the differences in percentage of collenchyma in the varities are only slight and may not be responsible for the marked differences in the appearance of rust pustules. The most resistant varities of *Triticum vulgare* have less collenchyma than the highly susceptible ones. In addition, she measured the thickness of the outer membranes and the cuticle layer of the cell of the epidermis of wheat peduncles. She found that in the highly susceptible varities, the outer cell walls were thin, and they were thus, less resistant to pustule rupture.

**Pal and Hassannain (1946)** studied the relationship between certain morphological characters and rust resistance of wheat varities. They found no relationship between the amount of collenchyma and rust resistance.

**Wilcoxson (1956)** compared collenchyma and sclerenchyma tissues as well as thickness of epidermis over the collenchyma tissues in stems of 34 wheat varities for their ability to resist attack by *Puccinia graminis* var. *tritici* He reported that stems

of resistant varities had small amount of collenchyma tissues broken into many single bands comparing with the susceptible ones which had large quantities of compound bands. He also added that the varieties in question did not differ in thickness of collenchyma cell walls. He also in (1958) studied the peduncle sclerenchyma tissues of Nugget wheat in relation to the development of pustules of *Puccinia graminis* var. *tritici*. He found delaying of pustules rupture and size as well as disease development and attributed this to the smaller intercellular spaces in the peduncle between the sclerenchyma tissues.

**Prasada (1964)** reported that the relative proportions of collenchyma and sclerenchyma vary in different parts of wheat stem and that these were important factors in determining the spread of the mycelium and the size of rust pustules.

**Naguib (1973)** studied the number of leaf hairs and stomata as well as the collenchyma to sclerenchyma ratio and the thickness of epidermal cells as different aspects of morphological resistance. He found that the number of leaf hairs and the number of stomata were independent to the degree of rust resistance. Also, the resistant varities used showed a smaller ratio of collenchyma to sclerenchyma and a thicker epidermis than the susceptible ones.

**Ragab *et al.* (1979)** studied the structure of glumes in resistant and susceptible wheat varities in relation to stripe rust (*P. striiformis*) resistance. They found that the glumes of the resistant varities had higher amount of sclerenchyma tissues compared with the susceptible ones. Moreover, they also found lower levels of parenchyma tissues vins of the resistant varities than in the susceptible ones.

**El-Sherif *et al.* (1977)** studied the relation between some morphological characteristics and stem rust resistance of some wheat varieties. They found that the resistant varieties contain a larger amount of sclerenchyma and a smaller amount of collenchyma tissues than the susceptible ones. Moreover, the ratio of collenchyma to sclerenchyma tissues was higher in the susceptible varieties than in the resistant ones. They concluded that there is a relation between rust resistance and the ratio of collenchyma to sclerenchyma tissues in the peduncle, and the percentage of collenchyma to sclerenchyma tissues was larger in the susceptible cultivar than the resistant ones. It was 58.6%, 37.3% and 18.4% in Giza 160, Giza 165 and Gemmeiza-1, respectively.

**Palmer and Wilcoxson (1982)** studied wheat peduncle structure in relation to slow rusting by *P. graminis* f. sp. *tritici*, they found that morphological and anatomical characteristics of the wheat peduncle varied among cultivars and there characters were not closely related to the development of stem rust.

**Imbaby (1995)** compared collenchyma and sclerenchyma tissues as well as thickness of epidermis over collenchyma tissues in leaf rust of 3 wheat varities for their ability to resist attack by *Puccinia recondita* f. sp. *tritici*. He reported that the average thickness of epidermis was 4.33$\mu$, 4.86$\mu$ and 4.66$\mu$ in Giza160, Giza165 and Gemmeiza-1, respectively when both of the cuticle and outer wall over the collenchyma were measured, it was found that the susceptible cultivar Giza160 was the highest (1.54$\mu$) followed by the mesothetic cultivar Giza 165 (1.46$\mu$) and then the resistant one Gemmeize-1 (1.44$\mu$). He also added that, in general the amounts of collenchyma tissues were smaller, in all cultivars

used, than the amounts of sclerenchyma tissues. Also, it was larger in the susceptible cultivar Giza160 (4.81 $mm^2$).

**Aly (1999)** revealed that highest value of epidermis thickness was recorded with Giza 139 variety followed by Sakha 93 and Sakha12. On the other hand, the highest value of cuticle and outer wall thickness was recorded with Sids-1 and Sakha 12 in Egypt. Regarding the measurements of collenchyma and sclerenchyma tissues in leaf blades of the same entries data indicated that Sids-1 exhibited the highest value of collenchyma followed by Sakha 10 and Sakha 93, respectively. On other hand, Sids-1 followed by Sakha 93 and Sakha 10 exhibited the highest area of sclerenchyma.

**Evaluation of certain wheat entries to stem rust disease:**

**Lowther (1951)** stated that certain wheat varieties were susceptible to stem rust at seedling stage but became resistant as they approached maturity, however sometimes the reaction was reversed. Mentana variety and some of it's progenies were resistant at seedling stage, whereas the their adult plants were completely susceptible.

**Shukla (1952)** found that the Kenya wheat varities were susceptible to race 15 of *P. graminis* f. sp. *tritici* and moderately susceptible to 15B at seedling stage, while they possessed a mature plant-resistance to race 15B at adult stage.

**Chakravarti and Hart (1959)** stated that wheat varieties *i.e.* "Lee", "Longdon" and "Sentry" retarded and slow down the increase of stem rust infection than the wheat variety "Carleton".

**Van der Plank (1963)** pointed out that there were two types of resistance *i.e.* horizontal and vertical resistance based on the reaction of the host and prevalent races of the pathogen. Horizontal resistance was uniformly active against all races of the pathogen. However, vertical resistance (perpendicular resistance) was more active against some races of a pathogen than others. He also mentioned that slow rusters characterized by a lower r-value. He found that r-value was most accurately measured during the early phases of disease.

**Van der plank (1968)** reported that the area under disease progress curve of wheat stem rust has been most successful criterion to compare between different disease severieties with different varities and losses.

**Sirry *et al.* (1970)** pointed out that stem rust incidence did not affect by growth stage for wheat cultivars *i.e.* Webster, Tosson, Ramona, Marquis and Reliance. On the other hand, wheat cultivars *i.e.* Lee, Giza 150 and Giza 155 showed mature plant resistance when inoculated with certain stem rust races.

**Wilcoxson *et al.* (1974)** found that area under disease progress curve, varied significantly with different varities, to stem rust severity, in field trials. They found that wheat varieties, Baart, Prelude and Marquis were most severely rusted (fast-rusters), however, Exchange, Thatcher, Webster, Redman, Mc Murachy, Kenya 58, Frontana and Idead 59 were least severely rusted (slow-rusters). While, Lee was intermediate (moderately slow-rusting).

**Mackenzie (1976)** described slow rusting reaction as a reduced rate of epidemic acceleration. He mentioned that slow rusting should have a lower apparent infection rate when compared

with susceptible cultivars subjected to the same pathogen population under the same environmental condition. This method was applied on the susceptible wheat cultivars (to stem rust) *i.e.* Pitic 62 and Penjamo 62 in comparison with cv. Bonza 55 for gross epidemiological attributes reduced spread and rate of rust increase.

**Skovmand *et al.* (1976)** found that Idead 59 rusted most slow (slow-ruster), Baart and Prelude rusted rapidly (fast–ruster) Lee, Kenya 58, Marquis and Thatcher lied in between (slow and fast rusters).

**Shaner and Finney (1980)** found that area under disease progress curve (AUDPC) was more sensitive criterion than apparent infection rate and they found that AUDPC was more accurate than both infection rate and mean percent disease severity under field hill plots condition.

**El-Daoudi *et al.* (1983)** pointed out that wheat cultivar "Giza 155" exhibited low level of disease severity, low AUDPC and less disease development (r-value) in both growing seasons (1979/80 and 1980/81) than the wheat cultivar "Chenab 70". They also found that, the two Egyptian wheat varities Giza 155 and Giza 156 have a resistance "partial resistance".

**Ragab *et al.* (1989)** indicated that the slow rusting cvs. Sakha 69, Sakha61, Sakha 92 Giza 162 and Baart had a lower rate of area under disease progress curve (AUDPC) while the higher AUDPC were evident to cultivars Sakha 8 and Giza 157 that were considered highly susceptible to stem rust.

**El–Daoudi *et al.* (1990)** tested seven Egyptian varities. which were classified to three groups based on infection type with stem rust *i.e.* Giza 162 was moderate resistant (MR), Giza 155,

Sakha 61 and Sakha 69 were moderate susceptible to susceptible (MS-S) and Giza 157, Sakha 8, and Giza 160 that were susceptible (S). They also found that Giza 157, Giza 160 and Sakha 8 wheat vars. showed the highest values of rate of disease increase (r-value) and area under disease progress curve (AUDPC).

**Mohamed (2001)** Evaluated 15 commercial wheat entries added to variety Little Club as a control against stem rust in Egypt during 1994-1997. The tested entries were divided into two categories according to their response to the causal agent in terms of AUDPC. First group: Giza 155, G. 157, G. 166, Sakha 69, Gemmeiza-1 and Gemmeiza-3, exhibited adult plant resistance. On the other hand, the second group: Giza 162, G. 163, G. 164, G. 165, Sakha 8, Sohage-2, Sohage-3, and Little Club, exhibited high susceptibility.

**Yield reduction of wheat genotypes against stem rust:**

**Rowell (1982)** stated that rust caused significant losses in yield and kernel weight but the percentage of loss was significantly less than that recorded with the more receptive cultivars. In the early stages of the epidemic, disease incidence and rate of disease increase were markedly less in the low receptive *i.e.* Purdue 5481 than in the more receptive *i.e.* Idead 59 and W 2691 (*Sr* $T_{t-1}$).

**Khalifa (1986)** found that nineteen out of sixty varieties were resistant while, 8 out of sixty varieties and lines categorized into three groups on the basis of stem rust reaction and tolerance ratio as follow: resistant, susceptible (tolerant) and susceptible (non-tolerant) varsities.

**Bassiouni *et al.* (1987)** reported that stem rust caused by *Puccinia graminis tritici.* in the cultivars *i.e.* Sakha 8 and Sakha 79 exhibited significantly reduced yield/plot, 1000-grain weight and test weight compared with controls sprayed with Triademefon. Also, they found that Sakha 8 was more tolerant than Sakha 79.

**El-Daoudi, *et al.* (1990)** observed that grain yield differed significantly among treatments and cultivars. The reduction in yield was parallel to rust severity, while 1000 kernel weight decreased as the severity of stem rust increased. However, the decrease varied among cultivars. Sakha 69 exhibited the best performance, at up 50% stem rust infection the reduction in kernel weight was less than 3%.

**Patterson, *et al.* (1990)** demonstrated that disease losses were estimated from unprotected and protected plot comparison of resistant and susceptible cultivars. The average of annual loss due to disease was estimated by 11.5%.

**Mc Grath and Pennypacker (1991)** found that rate and duration of grain growth were reduced by rust (*Puccinia graminis* f. sp. *tritici* and *P. recondita* f. sp. *tritici*). Rust had a greater impact on grain growth in 1986, when stem rust occurred alone, than in 1987, when both leaf and stem rusts were present, in 1986, growth rates were inversely related to disease severity.

**Sinha and Goel (1996)** observed different *P. graminis tritici* disease variables on wheat grain yield. The yield variability was best explained by multiple regression of 4 average coeffition of infection (ACI) values or by taking ACI and the rate of rust spread together. AUDPC partially explained the yield variability.

**Genetic studies for slow rusting under field condition:**

Wheat stem rust caused by *P. graminis tritici* is one of the most destructive diseases in Egypt. Generally, disease resistance has been known to be a simple inherited character since **Biffen (1905)**.

Genetic studies is the most accurate way of demonstrating diversity via the conventional genetic analysis **McIntosh, (1988)**.

**Baker (1966)** isolated dominant complementary genes in the resistant oat variety 'Bond' conditioning resistance to crown rust. Their presence and mode of action were confirmed by $F_2$ analysis when certain bulk $F_4$ lines produced in this manner were intercrossed and when one such line was crossed with 'Bond'.

**Simons *et al.* (1978)** reported that the gene action may be complementary. Genes at different loci or their products may interact to give higher level of resistance. They also mentioned that the complementary resistance require presence of two or more genes to be expressed.

**Knott (1982)** indicated that wheat stem rust resistance is a polygenic character affected by many gene pairs as well as environmental conditions.

**Raut *et al.* (1984)** stated that inheritance of seedling resistance to 6-races of (*P. graminis tritici*) in 5 crosses involving the cultivars A-1-8-1, Gulah and MACS-9 as susceptible and Gaza ED-1606, MACS-68 and Carthlicum-1582 as resistant parents. They found that resistance was dominant over susceptibility, with monodi- and trigenic control involved duplicated and complementary interactions.

**Ezzahiri and Roelfs (1985)** evaluated a population of 600 wheat lines representing 17 $F_2$ families of a cross between cv. Baart (susceptible) and cv. Era (resistant). Populations were evaluated for adult plant resistance to leaf rust. They showed that two complementary genes controlled resistance.

**Orlyuk and Lavrinenko (1985)** pointed out that resistance to stem rust was generally intermediate between the parental values though some cases of dominance or recessiveness was found.

**Singh and McIntosh (1987)** reported that the adult resistance of Chris and W 3746 to predominant pathotypes of *P. graminis tritici* appeared to be associated with the interaction of *Sr* 7a and *Sr* 12 genes at closely linked loci. But *Sr* 7a or *Sr* 12 alone conferred no observable resistance upon adult plants.

**Knott and Weller (1988)** proved that relatively few interactions among the genes were detected at the seeding tests. All involved small additive effects when *Sr* 7a was combined with either *Sr* 8a or *Sr* 9b. Interactions were much more common in the field tests. With race 56, the three 2 gene combinations of *Sr* 8a, *Sr* 9b and *Sr* 11 showed significant additive effects. With race 15B-1. In addition, the results indicated that *Sr* 9b and possibly *Sr* 11 had residual effects against race 15 B-1.

**Mishra *et al.* (1989)** pointed out that monogenic or digenic control of inheritance of resistance to stem rust *Puccinia graminis* was indicated in 3 exotic *T. durum* land races (ED 155 and ED 1096 of Egyptian origin and ED 404 from Turkey). Genetic diversity as observed among these wheat for adult plant resistance to race mixtures as well as for seedling resistance to 4 Indian *P. graminis* pathotypes 21 A-2, 40, 117 and 117 A-1. The genes conferring

adult plant resistance were, therefore, thought to be different from those conditioning seedling resistance.

**Bolate and Roelfs (1991)** found that continuous variation to Pgt-QCC in low infection types was found in the $F_2$. However, about 1 of 64 of the $F_2$ plants gave a reaction similar to that of the resistant parent indicating 3 recessive resistant genes.

**Shehab El-Din *et al.* (1991)** mentioned that $F_1$ means were close to resistant parent. They found dominance of resistance over susceptibility. Almost complete dominance in the $F_1$ and partial dominance in the $F_2$ were observed.

**Bai and knott (1994)** found that resistance to leaf rust race 15 and stem rust race 15 B-1 in each of the six *T. dicoccoides* accessions was conferred by a single dominant or partially dominant genes. In the diallel crosses, the dominance of resistance appeared to be affected by different genetic backgrounds. *Triticum dicoccoides* has considerable genetic diversity for rust resistance and is a promising source of new rust resistance genes for cultivated wheat.

**Johnson and Tanner (1994)** pointed out that durable resistance to *Puccinia graminis* (stem rust) was derived from *Triticum timopheevii,* the cultivars Hope and H44, rye and *Agropyron elongatum* [*Elymus elongates*].

**Reddy *et al.* (1994)** pointed out that stem rust resistance gene *Sr* 27 was successfully transferred from the Mexican wheat cv. W3353 into the Indian wheat cv. *Unnath kalyansona* via 2. successive back-crosses. The newly constituted lines were free of stem rust and also leaf and yellow rusts. The yellow rust resistance

was attributed to an unidentified *Yr* gene in the donor parent and it is proposed that *Yr* gene is linked to *Sr* 27.

**Sawhney and Joshi (1996)** observed that cultivars possessing *Sr* 2 in combination with certain other specific genes have maintained resistance to stem rust (*P. graminis*) within certain wheat in Indian germplasm.

# Materials and Methods

The present investigation was performed at the experimental farm of Sakha Agric. Res. Stn. and under the greenhouse of Wheat Dis. Res. Div., at the Plant Pathology Research Institute (PPRI), Agric. Res. Center (ARC), Giza, Egypt during 1998-2000.

The aim of the present study is to evaluate stem rust disease on certain wheat cultivar and entries, race dynamics and certain topics relevant to the genetics and physiology of stem rust.

**The present work included four topics:**

**I. Greenhouse experiments.**

A. Race identification by classic and recent systems.

B. Virulence formula for the resultant races and gene efficacy.

C. Gene postulation within certain wheat commercials.

**II. Labratorial experiments.**

A. Studying the components of partial resistance in certain wheat.

B. Histological studies from perspective of disease resistance.

C. Effect of stem rust infection versus leafs cutting on root weight.

**III. Field experiments.**

**IV. Genetical studies**

**Survey studies**

An annual survey was initiated during 1997/98 including various districts at the Northern governorates of Egypt viz. Kafr El-Sheikh, Dakahleia, Damietta, in addition to the governmental farms and the breeding programme farms of wheat located at Sakha Agic. Res. Stn.

likewise, the survey included different local and exotic wheat varieties and lines.

The samples were stems and/or leaves of wheat showing characteristic symptoms of stem rust disease. These samples were kept in paper envelops and preserved at room temperature overnight and located in disiccator over calcium chloride till usage.

The survey was repeated twice *i.e.* 1997/98 and 1998/1999 reaching to a total number of samples estimated by 70 during the two seasons.

**Rust increase and purification**

Each stem rust sample was increased on seedlings of highly susceptible variety "Little Club" grown in plastic pots (10 cm. diam.) filled with clay soil. The methods of **Stakman, *et al.* (1962)** were applied in which the 7-10 day old seedlings were moistened and rubbed between fingers. In these methods, initially established on the susceptible variety wheat seedlings and reproduced by repeating inoculation using single pustule technique. The inoculated seedlings were incubated in an apparatus with 90-100% humidity and 20-24 °C under the stress of complete darkness for 24 hrs. The incubated seedlings were transferred to the growth cabinets for 10-12 day till stem rust symptoms began to be visually recognized.

After the initiation of disease symptoms the coalescent sori were excluded, however the single pustules were individually picked up and reinoculated on new Little Club seedlings. The same steps were repeated many times for the collected samples, using single pustules for inoculation.

## I. Greenhouse experiments:

These experiments included physiologic races identification, distinction of effective resistance gene, virulence formula and postulated genes conferring resistance to stem rust.

### Physiologic race identification:

The main objectives of this study is to: identify the predominant physiologic races in the region of North Delta using both of the traditional method **(Stakman, *et al* 1962)** and the recent one **(Roelfs & Marten, 1988)**.

### The traditional method:

The main objectives of the present experiment are to identify stem rust races predominant in Egypt particularly in the Northern governorates of Egypt (Kafr El-Sheikh, Dakahleia and Damietta), their virulence against the cultivated varities and determination of effective genes acting against stem rust uredospore population.

To start such task a survey was carried out including different localities and cultivars during 1998/1999 and 1999/2000. The collected samples were selected according to the presence of stem rust symptoms on it.

The method of **Stakman *et al.* (1962)** was precisely applied, starting by multiplication of the preserved samples on the highly susceptible check "Little Club". Then, the increased samples were purified using the single pustule technique, by picking up 3-5 single pustules and increased on Little Club seedlings grown in single isolated pots and allowed to be increased to be utilized for race identification.

In the same time, the stem rust wheat differentials varieties listed in Table (1) were sown at rated 5 – 7 seeds in 10 cm. diam. plastic pots

clay soil. Irrigation, fertilization... etc. were performed as recommended.

Seedlings at 7-10 days old of the differential varieties were inoculated and were put in the apparatus at 20-24 °C for 24 hr. in darkness under the stress of 100% (RH). There after the seedlings were transferred to the growth cabinets under the day light intensity and left for 10-12 days, till the symptoms could be visually recognized.

Disease reactions were determined according to the (0 - 4) scale adopted by **Stakman, *et al.* (1962)** which is clarified in Table (2).

On the basis of the differential reaction of the rust isolates on the standard differential varieties, the races were nomenclatured.

**Table (1).** The standard differential varieties used for identification of stem rust races.

| No. | The varities | | Designation |
|---|---|---|---|
| 1 | **Little Club** | (*Triticum compactum*) | C.I. 4066 |
| 2 | **Marquis** | (*Triticum vulgare*) | C.I 3641 |
| 3 | **Reliance** | (Triticum *vulgare*) | C.I 7370 |
| 4 | **Kota** | (*Triticum vulgare*) | C.I 5878 |
| 5 | **Arnautka** | (*Triticum durum*) | C.I 1493 |
| 6 | **Mindum** | (*Triticum durum*) | C.I 5296 |
| 7 | **Spelmar** | (*Triticum vulgare*) | C.I 6236 |
| 8 | **Kubanka** | (*Triticum vulgare*) | C.I 2094 |
| 9 | **Acme** | (*Triticum vulgare*) | C.I 5284 |
| 10 | **Einkorn** | (*Triticum monococcum*) | C.I 2433 |
| 11 | **Vernal** | (*Triticum dicoccum*) | C.I 3686 |
| 12 | **Khapli** | (*Triticum dicoccum*) | C.I 4013 |

**Table (2).** The infection types, infection class and the stem rust reaction adopted at the greenhouse test (after **Stakman *et al.*, 1962**).

| Infection type | Infection class | Stem rust reaction |
|---|---|---|
| **0** | **Immune ( I )** | Neither uredia nor other indication of infection. |
| **0;** | **Nearly immune ( H.R )** | No uredia, but hypersensitive flecks are present. |
| **1** | **Resistant ( R )** | Uredia minute, surrounded by distinct necrotic area. |
| **2** | **Moderately resistant ( M.R )** | Uredia small to medium, usually in green islands surrounded by a decidly chlorotic or necrotic border. |
| **3** | **Moderately susceptible ( M.S )** | Uredia are medium in size, no necrosis but chlorotic areas may be present. |
| **4** | **Susceptible ( S )** | Uredia large, no necrosis but chlorosis. |
| **X** | **Heterogeneous** | Urdia variable, sometimes including all infection types and intergradations between them on the same leaf. |

**The recent race nomenclature system:**

By method of **Stakman *et al.* (1962),** nothing was known about the resistant genes included in the wheat differential varieties but recently after the discovery of wheat isogenic lines, the resistant genes involved in each differential became known.

This system was adopted by **Roelfs and Martens (1988)** they used a included 12 differential hosts, each with single stem rust resistance gene. They are classified in 3 subsets, as follows:

**The 1st subset** included differential hosts with *Sr* 5, *Sr* 21, *Sr* 9e and *Sr* 7b resistant genes.

**The 2nd subset** included differential hosts with *Sr* 11, *Sr* 6, *Sr* 8a and *Sr* 9g resistant genes.

**The 3rd subset** included differential hosts with *Sr* 36, *Sr* 9b, *Sr* 30 and *Sr* 17 resistant genes.

The subsets are indicated in Table (3). These subsets are considered a new set of the international differential hosts for characterizing the virulence of cultures of *P. graminis* f. sp. *tritici* including the host resistance genes above mentioned. The traditional inoculation techniques, purification and race identification previously mentioned elsewhere were applied herein.

In the recent system each race is designated by a three-letter code (Pgt-code) followed by a hyphen and a listing of those host genes in the resistant set on which the race was virulent. The *Sr* differential hosts are placed in four sets and a letter is assigned to each of the 16 possible combinations *i.e.* ($2^4$) of the interactions, the letters from B to T, except vowels letters are used to identify races.

The resultant reactions were matched to those in the table aiming to reach the modern nomenclature system according similarity with the differential hosts.

**Table (3).** Pgt-code for the 12 Pgt differential hosts for *Puccinia graminis* f. sp. *tritici* in ordered subsets of four [b].

| Pgt-code | Subset [a] | Infection type produced on host lines with *Sr* | | | |
|---|---|---|---|---|---|
| | 1 | 5 | 21 | 9e | 7b |
| | 2 | 11 | 6 | 8a | 9g |
| | 3 | 36 | 9b | 30 | 17 |
| **B** | | Low | Low | Low | Low |
| **C** | | Low | Low | Low | High |
| **D** | | Low | Low | High | Low |
| **F** | | Low | Low | High | High |
| **G** | | Low | High | Low | Low |
| **H** | | Low | High | Low | High |
| **J** | | Low | High | High | Low |
| **K** | | Low | High | High | High |
| **L** | | High | Low | Low | Low |
| **M** | | High | Low | Low | High |
| **N** | | High | Low | High | Low |
| **P** | | High | Low | High | High |
| **Q** | | High | High | Low | Low |
| **R** | | High | High | Low | High |
| **S** | | High | High | High | Low |
| **T** | | High | High | High | High |

[a] Pgt-code consists of the designation for subset1 followed by that for subset 2, etc. for example, race TTT is virulent (high infection type) on all 12 differential hosts and race DCL is virulent on differential hosts with *Sr* 9e, 9g and 36. Low and high infection types indicate an incompatible and a compatible host-pathogen interaction, respectively.

[b] Cited after **Roelfs and Martens (1988)**.

The genotypes in the differential varieties were indicated here Table (4) as an example for explanation.

**Table (4).** Genotype of the hosts used in the Stakman series of differential hosts for *Puccinia graminis* f. sp. *tritici* as currently understood [c].

| Differential hosts [a] | *Sr* gene (s) | Remarks [b] |
|---|---|---|
| **Little Club** | L.C | Generally ineffective. |
| **Marquis** | 7b, 18, 19, 20, X | *Sr* X is important in N. America. |
| **Reliance** | 5, 16, 18, 20 | *Sr* 5 is included in the Pgt-set. |
| **Kota** | 7b, 18, 19, 28, Kt'2' | *Sr* 28 important in Indian subcontinent. |
| **Arnautka** | 9d, 9a | Differential in N. America. |
| **Mindum** | 9d, 9a, 9b | Differential in N. America. |
| **Spelmar** | 9d, 9a, 9b | Differential in N. America. |
| **Kubanka** | 9g, 9c | *Sr* 9c detected in N. America. |
| **Acme** | 9g, 9d | *Sr* 9d detected in N. America. |
| **Einkorn** | 21 | *Sr* 21 is included in the Pgt-set. |
| **Vernal** | 9e | *Sr* 9e is included in the Pgt-set. |
| **Khapli** | 7a, 13, 14 | *Sr* 13 is an important resistance. |

[a] **Stakman *et al.* (1962).**

[b] *Sr* LC, 14, 16, 18, 19, 2d and Kt'2' are generally ineffective worldwide, except in sexually reproducing populations and against *P. graminis* f. sp. other than *tritici*. *Sr* a, b, c and d are postulated to be present based on host response and are effective to some North America cultures. *Sr* 7a results in a low infection type that is too unstable to use with current technology.

[c] Cited after **Roelfs and Martens (1988).**

**Gene postulation in certain Egyptian wheat entries against stem rust at seedling stage:**

The main objective of the present experiment is to determine the resistant genes acting against stem rust disease within certain local wheat commercials.

Twenty-one wheat entries representing the Egyptian germplasm indicated in Table (5) in addition to known stem rust resistance genes *i.e. Sr*'s Table (6) were tested for stem rust resistance using 30 cultures of stem rust *Puccinia graminis tritici* obtained from collected samples of 1998/1999.

These entries were grown in the greenhouse at Giza Agric. Res. Sta., during 1999/2000, in plastic pots, with 10 cm. diam. Each pot contained four varieties in each corner clockwise.

Inoculation and incubation were performed in moist chambers at 20-24 °C. Inoculated plants were held at approximately 100% relative humidity for 24 hrs. Plants were returned to the greenhouse bench at 22 - 24°C till disease on set. Rust reaction on the first leaf was recorded (22 days after sowing) following the method adopted by **Stakman, et al. (1962)**.

The infection type on each cultivar or near isogenic line was classified at the scale of (0 - 4). 12 days after inoculation, where infection types (IT) *i.e.* R= (0, 0;, 1 and 2) were classified as low infection type (LIT) or resistant and S= (3 and 4) were considered as high infection types (HIT), or susceptible using a method similar to those of **Browder, (1973)** and **Statler (1984)** to determine the probable resistance genotypes of the cultivars for each pair of tested hosts.

Table (5). List of Egyptian wheat entries and their pedigree which were evaluated through out the present study .

| No. | Vars. | Pedigree |
|---|---|---|
| 1 | Gemmeiza-3 | BB/7C*2//Y50/KAL*3 × Sakha 8/4 / PRV / WW/5 / 3 / BJ / "S" // ON * 3 / BON. |
| 2 | Gemmeiza-5 | Vee"S"/SWM6525Gm.4017-1Gm.7Gm.-3Gm.-0Gm. |
| 3 | Gemmeiza-7 | CMH74A.630/SX//SER182/AGENTC'Gm.4611-2Gm.-3GM.-1Gm.-0Gm. |
| 4 | Giza 160 | (Regent 975-11 × Giza $139^2$) × Mida Cadet × Hindi 62. |
| 5 | Giza 164 | KVS – BUHO "S" × KAL - B.B (VEERY "S" ). |
| 6 | Giza 165 | CNO / MFD /MAN "S". |
| 7 | Giza 167 | Au/up301//GLL/SX/Pew"s"141Mai"S"/May"S"//Pew"S". |
| 8 | Giza 168 | MRL/BUC//Seri. |
| 9 | Sakha 8 | INDUS / NORTENO. |
| 10 | Sakha 61 | INIA – RL 4220 $\times 7_C$ / YR "S". |
| 11 | Sakha 69 | INIA – RL4220 × $7_C$ / YR "S" . |
| 12 | Sakha 202 | BL1133/3/CMH79A.955*2/CNO79//CMH79A.955/Bow"S". |
| 13 | Sids-1 | HD2172/Pavon "S"//1158.57/Maya74"S". |
| 14 | Sids-6 | Maya "S"/Man "S"//CMH74A.592/3/Sakha8*2SD/10002. |
| 15 | Sids-7 | Maya "S"/Man "S"//CMH74A592/3/Sakha8*2SD/10002. |
| 16 | Sids-8 | Maya "S" /Man "S"//CMH74A592/3/Sakha8*2S D/10002. |
| 17 | Sids-9 | Maya"S"/Man"S"/4/CMH72.428/MRC//JUP/3/CMH74A582/5/ Giza 157*2SD10003. |
| 18 | Beni Sweif-1 | Jo"s"/AA"s"//Fg"s". |
| 19 | Sohag-1 | Gdovz 469/3/Ja"s"//bi-30/Lds. |
| 20 | Sohag-3 | Mexi."s"/MGHA*51792//Durum 6. |

**Table (6).** Cultivars and lines of wheat carrying single genes for resistance used to identify stem rust cultures in Canada. (Green 1981).

| Genes for resistance | Typical resistant infection type | | Cultivar or line |
|---|---|---|---|
| | Seedling [a] | Adult [b] | |
| *Sr 5* | 0 | I | Prelude*6/Reliance |
| *Sr 6* | 0;, X | R | Mida-McMurachy-Echange/6*Perlude |
| *Sr7b* | 2+- | MS | Chinese Spring/Hope (C.I. 14165) |
| *Sr8a* | 2+- | MS | Chinese Spring/Red Egyptian (C.I. 14165) |
| *Sr 9b* | 2, 2, 3 | MR | Prelude*4// Marquis*6/Kenya 117A |
| *Sr 9d* | ;2- | MR | H-44-24/6*Marquis |
| *Sr 9e* | ;, ;1+, 2 | R | Vernstein W3196 |
| *Sr 9g* | 2- | MR | Lee |
| *Sr 11* | 1+, ;2 | R-MR | Chinese Spring/Timstein C.I.14171 |
| *Sr 17* | 0;1 | R | Prelude/8*Marquis*2//Esp 518/9 |
| *Sr 21* | 0; | R | *Tricticum monococcum* |
| *Sr 25* | 2 | MS-S | *Agropyron elongatum* |
| *Sr 26* | ;2- | MR | *Agropyron elongatum* |
| *Sr 27* | 0; | I | WRT 238-5 |
| *Sr 29* | 2- | MS | Prelude/8*Marquis//Etoil de Choisy |
| *Sr 30* | 2 | MS | Webster |
| *Sr 36* | 0;, X | I, Tr S | Prelude*4/NHLII.64.62.1 |
| *Sr Gt* [c] | 2+ | MS | Gamut |
| *Sr* $T_{t-1}$ | 2 | R | W269L*Sr*$T_{t-1}$ |

[a] Low infection types at 18 °C, may vary at other temperature.
[b] I = immune, R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, Tr S = trace susceptible.
[c] Cited after Green (1981).

Matching or comparing the cultivars with unknown resistance genes (host B) to the isogenic lines each carrying single known gene for resistance to stem rust (host A) was performed. The infection types of tested cultivars were classified into four categories according to the following scheme

| | | **Host B** | |
|---|---|---|---|
| | | **Resistant** | **Susceptible** |
| **Host A** | **Resistant** | LIT:LIT | LIT:HIT |
| | **Susceptible** | HIT:LIT | HIT:HIT |

In which the absence of LIT:HIT or HIT:LIT between host (B) and known gene host (A) indicated the presence of such gene's' in the test host exhibited the symbol (-0) when the host (B) proved to have (HIT):(LIT) comparing to host (A), this behaviour would indicate the absence of such gene in host (B) and consequently it would have the symbol (-). The presence of LIT in (B) HIT in (A) indicated the presence of such gene in host (B) and it may have another one and have the symbol (0) .The presence of pathotypes having HIT:LIT and LIT:HIT in the comparisons indicated that either of the hosts did not have the same gene and characterized by the Symbol (+).

**II. Labratorial experiments including :**

**A. Components of partial resistance in certain local wheat entries :**

The present experiment was conducted at Plant Dis. Res. Lab. (Sakha Agric. Res. Stn.) during 1999/2000. The main objective of such experiment is to study the components of partial resistance in certain wheat cultivars against stem rust.

Fourteen Egyptian wheat cultivars showing different levels of rust severity were specified in such studied entries i.e. Gemmeiza-1,

Gemmeiza-5, Gemmeiza-7, Gemmeiza-9, Giza 160, Giza 163, Giza 164, Giza 167, Giza 168, Sakha 8, Sakha 61, Sakha 93, Sakha 202 and Little Club. Two physiologic races of *P. graminis* f. sp. *tritici* races 11 and 15 obtained from the Wheat Disease Res. Section, Agriculture Research Center, Giza, Egypt, were used for the inoculation of such varieties at seedling stage under greenhouse condition.

The method of inoculation, incubation and rust records were performed according to the methods of **Stakman *et al.* (1962).**

The components of slow rusting *i.e.* number of infection sites per square centimeter, number of erupted and non-erupted pustules per square centimeter, latent period, colony area and uredium size estimates were measured for each tested entry and for each physiologic race according to **Hooker (1967), Ohm and Shaner (1976), Samborski *et al*, (1977) and Zwatz (1980).**

Segments with 1-3 cm. long were cut-off from the middle part of inoculated leaf blades at the end of sporulation period. The segments were cleared, stained and prepared for microscopic examination by using the whole-leaf-clearing and staining technique described by **Shipton and Brown, (1962).** In which, the infected leaf segments were immersed in 10-15 ml of alcoholic lactophenol cotton blue, immediately after cutting. The solution consisted of 1 part lactophenol cotton blue to 2 parts 95% alcohol. lactophenol cotton blue solution was prepared as follow:

| | | |
|---|---|---|
| Phenol | ..... | 10 g. |
| Glycerin | ..... | 10 ml |
| Lactic acid | ..... | 10 ml |
| Cotton blue | ..... | 0.02 g. |
| Distilled water | ..... | 10 ml |

The solution, (containing leaf segments) was boiled and simmered for one minute. After the leaf segments sank, the solution was boiled again for ½ minute. Leaf segments were allowed to remain in the stain for approximately 48 hr. at room temperature. Then, the leaf segment were removed, rinsed in water and placed in chloral hydrate (5 gm. chloral hydrate + 2 ml distilled water) for 30-50 minutes.

The cleared leaf segments were then mounted on microscope slides in 50% glycerin for examination using ordinary light microscope. The mycelium was stained with cotton blue and may be distinguished by its blue purple color, while other leaf tissues were cleared with chloral hydrate. Colony diameter was measured by using an equilibrium ocular micrometer of light microscope and its area was estimated as an ellipse, using following formula:

$$\textbf{Colony area (size)} = \tfrac{1}{4}\ \textbf{(length} \times \textbf{width)} \times \pi$$

According to **Tomerline (1984)**. The colony area was measured for each entry at 15 days after inoculation (at sporulation over) until 50% of pustules opened i.e. latent period.

**B. Histological studies**

The presented experiment was directed to study the anatomical factors affecting resistance to stem rust in certain wheat varieties.

Four Egyptian wheat cultivars (*Triticum aestivum* L.) with different levels of resistance to stem rust were used at seedling and adult stage to determine the proportions of the anatomical characters *i.e.* thickness of epidermis, the outer wall, cuticle over the sclerenchyma and chlorenchyma tissues in the stem and leaves.

These entries were Sakha 93, Sakha 92, Sids 1, Sids 5. These entries were supported from rust nursery at Sakha Research Station. The

flag leaves and stems of each entries were cut-off into segments approximately 3 cm. in length and immediately immersed in formalin acetic acid (FAA). They were mounted in paraffin wax and cross sections were made using a sliding microtom, thereafter. Sections were then stained using saffranin and light green combination, then mounted in Canda balsam for microscopic examination following the method adopted by **Johansen, (1940)**.

Five cross sections (5 $\mu$ thick) from each cultivar were photographed using a photomicrograph at 200 × magnification, to illustrated collenchyma and sclerenchyma area. These area were measured using a micrometer thickness of the epidermis and the combined thickness of the outer wall and cuticle over the collenchyma tissues were also measured by the micrometer.

**C. Effect of stem rust infection versus leaf cutting on root weight:**

The main objective of this experiment is to estimate the effect of stem rust infection comparing to leaf cutting on root weight of some wheat varieties which are different in there reaction to stem rust.

To carry out this experiment 4 wheat varieties *i.e.* Giza 160 (susceptible), Giza 165 (susceptible), Giza 167 (tolerant) and Sakha 61 (moderate susceptible).

Split split plot design with 3 replications was adopted for the experiment. The main treatments were: represented by 4 wheat entries the abovementioned varieties.

Subtreatments were: (A) Artificially inoculated pots seedlings with stem rust. (B) Seedlings subjected to leaf cutting. (C) Control treatment (left without inoculation or cutting).

However the sub-sub treatments were represented by the intervals at which the roots were weighted *i.e.* 6 days intervals starting from disease on set the experimental unit was represented by 30 cm. diam. clay pot sown with 15 seed of each cultivar. Irrigation, fertilization, ... etc. were carried out according to the technical recommendation of the crop.

Artificial inoculation was carried out on 7 – 10 day old seedlings following the baby cyclone technique adopted by **Tervet and Cassel (1951)** in which the spore powder of uredospore mixture of the available physiologic races of *Puccinia graminis tritici* was mixed with talcum powder at the rate of (1:20) (w:w). After disease onset about half of each developed leaf of the healthy seedlings was cut, the fresh weights of roots in grams were recorded at 3 stable intervals, *i.e.* 15 days of sowing and 6 days thereafter. However, the control treatment was left without cutting or artificial inoculation.

**III. Field experiments:**

**Evaluation of certain wheat entries to stem rust disease during 1998/99 and 1999/2000 growing season:**

The main objective of the present experiment is to evaluate certain commercial entries against the disease (stem rust) from the perspective of yield parameters *i.e.* 1000 k.w and ten spike weight likewise the reduction (%).

On the other hand, disease parameters were taken into consideration *i.e.* disease reaction expressed in (ACI) and area under disease progress curves (AUDPC).

Twenty one spring wheat entries (*Triticum aestivum* L.) were chosen for this experiment namely: Sids-1, Sids-6, Sids-7, Sids-8, Sids-

9, Giza 157, Giza 160, Giza 164,Giza 165, Giza 167, Giza 168, Sakha 8, Sakha 61, Sakha 69, Sakha 202, Gemmieza-3, Gemmieza-5, Gemmieza-7, Sohag-1, Sohag-3 and Bani Sweif-1, these entries were kindly supported by wheat Res. Section at Sakha Agric. Res. Stn.

Split plot design with 3 replications was performed in this experiment, since the main plots were two methods of application:

(1) Severe artificial inoculation with stem rust inoculum using a mixture of stem rust isolates.

(2) Complete protection, using the systemic fungicide "Sumi-8 EC" at the rate of 0.35 ml/l. water/plot was applied on healthy plants to keep them free of stem rust infection.

The subplots included 21 local wheat entries. The artificial inoculation was carried out using the method adopted by **Tervet and Cassell (1951)** in which a mixture of stem rust isolates was added to talcum powder at the rate of (1:20) w:w the application was performed between late tillering and booting stage. Inoculation was done just before sunset where plants were moistened and rubbed to remove the waxy layer, then rust inoculum was sprayed at the spreader and irrigated thereafter.

Regarding the chemical application, Sumi-8 EC "diiniconazole" -1- (2,4-Dichlorophenol) -4,4 dimethyl–2 (1, 2, 4-triozole-1yl)- Penten-3-01" was applied on healthy plants (control) at the rate of 0.35 ml/L as recommended, soon at the inoculation treatment and repeated 3 times at 10 days intervals.

Regarding the subtreatment: 21 commercial wheat varieties were sown in 1-5 m. long. 2 rows each at 3 g. seed rate using the broadcasting method. The experiment was surrounded with susceptible spreader "Little Club". Irrigation, fertilization and weed control....etc. was

carried out according to the technical recommendations of the crop. Disease records were determined 10 day after inoculation and continued every 8 days intervals thereafter, in terms of IT (infection type) data according to **Stakman, *et al.* (1962)**.

Data were transformed to ACI (Average Coefficient of Infection) according to the Cobb scale adopted by **Saari and Wilcoxson (1974)** in which:

| | | | | | |
|---|---|---|---|---|---|
| **0** | **=** | **0.0** | **M** | **=** | **0.6** |
| **R** | **=** | **0.2** | **MS** | **=** | **0.8** |
| **MR** | **=** | **0.4** | **S** | **=** | **1.0** |

While AUDPC was estimated using the equation proposed by **Pandy, *et al.* (1989).**

$$\mathbf{AUDPC = D\ [\ \frac{1}{2}\ (Y_1 + Y_k) + Y_2 + Y_3 + .... + Y_{k-1}]}$$

**where:**

**D** = time interval.

$(Y_1 + Y_k)$ = Sum of first and last disease scores.

$(Y_2 + Y_3 + \ldots + Y_{k-1})$ = Sum of all in-between disease scores.

Reduction (%) in grain yield was estimated according to the equation of (**Calpouzos *et al.*, 1976).**

$$\mathbf{Reduction\ (\%) = (\ 1 - Yd / Yh\ ) \times 100}$$

**where:**

**Yd** = Yield of diseased plants.

**Yh** = Yield of healthy plants.

All data obtained were statistically analyzed for each season individually. Significant difference among entries were tested by the

analysis of variance test of a split plot design with 3 replicates as outlined by **Snedecor and Cochran (1967).** The difference among the means of the entries tested was compared by using Dunkan's New Multiple Range Test.

**IV. Genetic studies for slow rusting under field condition:**

The main objective of the present studies is the determination of the genetic factors governing the inheritance of this character at adult plants as a procedure for stem rust resistance. To carry out this experiment, six wheat entries were assigned for this purpose *viz*: Giza 167, Sakha 8, Sakha 61, Sakha 69, Sids–8 and Gemmeiza-3. This selection was determined on the basis of 4 seasons testing to stem rust infection. It was concluded that Sakha 8 exhibited fast rusting, while Gemmeiza-3 gave slow rusting and the rest of entries were considered to be having intermediate response. The pure seed of these parental wheat material were kindly supported by the Wheat Research Division, located at Sakha Agric. Res. Station, during 1998/99.

These materials were simultaneously sown in rows with 1.5 m. long and 30 cm. apart each row received 15 seed with 10 cm sowing distance.

The main objective of sowing these materials in this season was to carry out hybridization or crossing. The experimental unit included 3 rows of each cultivar. The cultural practices *i.e.* irrigation fertilization, ... etc. was performed according to technical recommendations of the wheat crop.

A half diallel cross series was performed between these cultivars and advanced to the $F_1$ plants listed in Table (7). The resultant seed were divided into two parts, one was grown to be crossed to their respective parents while the other part was saved to the final experiment.

Table (7). The $F_1$ generation resulting from 15 crosses made among 6 selected Egyptian wheat varieties during 1999/2000.

| No. | $F_1$ generation |
|---|---|
| 1 | Giza 167 × Sakha 8 |
| 2 | Giza 167 × Sakha 69 |
| 3 | Giza 167 × Sakha 61 |
| 4 | Giza 167 × Gemmeiza-3 |
| 5 | Giza 167 × Sids-8 |
| 6 | Sakha 8 × Sakha 69 |
| 7 | Sakha 8 × Sakha 61 |
| 8 | Sakha 8 × Gemm.-3 |
| 9 | Sakha 8 × Sids-8 |
| 10 | Sakha 69 × Sakha 61 |
| 11 | Sakha 69 × Gemm.-3 |
| 12 | Sakha 69 × Sids-8 |
| 13 | Sakha 61 × Gemm.-3 |
| 14 | Sakha 61 × Sids-8 |
| 15 | Sakha 69 × Gemm.-3 |

The final comparative experiment for each cross was conducted in 3 replicates during 2000/2001 growing season each replicate contained 1, 1, 1, and 6 rows for $P_1$, $P_2$, $F_1$, $F_2$, respectively. with 20 cm row spacing. The experiment was surrounded with 1 m belt of highly susceptible wheat cultivars to serve as 'spreader' for rust uredospores through out the season **Shehab *et al.* (1991).**

At booting stage, the spreader plants were inoculated following the method adopted by **Tervet and Cassel (1951),** as previous mentioned.

Rust reaction was recorded after 10-15 day of inoculation, following the scale adopted by **Stakman *et al.* (1962).**

The infection type frequency distribution for the $P_1$, $P_2$, $F_1$ and $F_2$ was estimated under field condition. Field response was converted into

an average coefficient of infection (ACI) following the method proposed by **Saari and Wilcoxson (1974)**. In this method the rust reaction could be obtained by multiplying the rust severity by an assigned constant value according to the infection type *i.e.* 0.2, 0.4, 0.6, 0.8 and 1 for R, MR, M, MS and S, respectively.

For studying the inheritance of slow rusting resistance, $F_2$ plants were categorized into groups depending on their infection type and disease severity under field conditions. The frequency distribution values for stem rust severities also were computed to the abovementioned populations at adult stage in the open field. The mode of inheritance, goodness of fitness to the expected ratios of the phenotypic classes, concerning stem rust severity and infection types were determined by $\chi^2$ analysis which was adopted by **Steel and Torrie, (1960).**

# Experimental Results

**Survey studies:**

The obtained results gave evidence to presence of stem rust disease at the districts of the Northern governorate of Egypt in a frequency ranged between (10% - 40%). Most of the samples were originated from Kafer El-Sheikh. Most of the exotic materials (samples) were received from the breeding programme.

The visible examination indicated that infected samples (*i.e.* stem or leaves and leaf sheath) exhibited uredial pustules conspicuously erumpent with tettared epidermal tissues at their margins. They may erupt through both leaf surfaces and tend to be longer on the underside. The pustules were oval elongate or spindle-shaped and up to 3 × 10 mm in size. Uredispores are 15-24 × 21-40 $\mu$m, orange-red, dehiscent and oval, oblong or ellipsoid. In case of severe infection uredial sori tend to coalescence. These results fit the characterization of *Puccinia graminis* Pers. f. sp. *tritici* Eriks. & Henn. and the concerned disease *i.e.* wheat stem rust.

**I. Greenhouse studies:**

**Physiologic race identification:**

Data presented in Table (8) revealed that during growing season of 1998/1999, 6 physiologic races *i.e.* 11, 14, 15, 17, 19 and 39 were found. The more frequent one was race no. 11 (40.00%) followed by 19 (16.67%), 15, 17 (13.33%), 39 (10%) and 14 (6.67%).

It is clear from Table (8) that race 11 was virulent to all the wheat differentials except Vernal and Khapli; while, race 14 was avirulent to Marquis, Reliance, Kota, Vernal and Khapli however; race 15 was avirulent only to Khapli. Race 17 was avirulent to Reliance, Vernal and Khapli; while race 19 was avirulent to Marquis, Reliance, Vernal and Khapli and race 39 was avirulent to Marquis, Vernal and Khapli.

**Table (8).** The prevailing physiologic races of *Puccinia graminis* f. sp. *tritici* at the Northern governorates of Egypt, expressed in infection types and identified during 1998/1999.

| No. | Differential varieties | Isolates | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Little Club | S | S | S | S | S | S |
| 2 | Marquis | S | R | S | S | R | R |
| 3 | Reliance | S | R | S | R | R | S |
| 4 | Kota | S | R | S | S | S | S |
| 5 | Arnautka | S | S | S | S | S | S |
| 6 | Mindum | S | S | S | S | S | S |
| 7 | Spelmar | S | S | S | S | S | S |
| 8 | Kubanka | S | S | S | S | S | S |
| 9 | Acme | S | S | S | S | S | S |
| 10 | Einkorn | S | S | S | S | S | S |
| 11 | Vernal | R | R | S | R | R | R |
| 12 | Khapli | R | R | R | R | R | R |
| Physiologic races identity | | 11 | 14 | 15 | 17 | 19 | 39 |
| Number of races | | 12 | 2 | 4 | 4 | 5 | 3 |
| Frequency of races (%) | | 40.00 | 6.67 | 13.33 | 13.33 | 16.67 | 10.00 |

- Total number of races was estimated 30.

Data in Table (9) revealed that during the growing season of 1998/2000, 5 physiologic races namely 11, 15, 17, 39 and 218 were recorded the more frequent one was race 11 (47.5%) followed by 15 (40%), 39, 218 (5%) and 17 (2.5%). Race 218 was avirulent to Kota and Khapli.

**Table (9).** The prevailing physiologic races of *Puccinia graminis* f. sp. *tritici* at the Northern governorates of Egypt, expressed in infection types and identified during 1999/2000.

| No. | Differential varieties | Isolates | | | | |
|---|---|---|---|---|---|---|
| 1 | Little Club | S | S | S | S | S |
| 2 | Marquis | S | S | S | R | S |
| 3 | Reliance | S | S | R | S | S |
| 4 | Kota | S | S | S | S | R |
| 5 | Arnautka | S | S | S | S | S |
| 6 | Mindum | S | S | S | S | S |
| 7 | Spelmar | S | S | S | S | S |
| 8 | Kubanka | S | S | S | S | S |
| 9 | Acme | S | S | S | S | S |
| 10 | Einkorn | S | S | S | S | S |
| 11 | Vernal | R | S | R | R | S |
| 12 | Khapli | R | R | R | R | R |
| **Physiologic races identity** | | **11** | **15** | **17** | **39** | **218** |
| **Number of races** | | 19 | 16 | 1 | 2 | 2 |
| **Frequency of races (%)** | | 47.50 | 40.00 | 2.50 | 5.00 | 5.00 |

- Total number of races was estimated 40.

Data presented in Table (10) revealed the virulence formulas of 6 physiologic races of *P. graminis tritici*. originated from 30 single pustules and their frequency. These data indicated that formulae *i.e.* 26, $Gt^+$ and 9e, 26, 36, $Gt^+$ were the more frequent one comparing with the rest. On the other hand, race ES15-13 proved to be the more virulent one, since it was virulent to 16 *Sr*'s out of 17. The reverse was true with ES19-25 which was virulent to only 7 *Sr*'s out of 17. The rest of races lied in between.

As regard the gene efficacy against stem rust population during 1998/1999, data presented in Table (11) indicated that *Sr* 26 occupied the first rank of effectiveness (83.33%) followed by *Sr* 9e (76.67%), and *Sr* 8a (40.00%). The rest of resistant genes exhibited efficacy ranged between (0.00 % and 33.3%) *Sr* 9d exhibited the highest virulence ratio (100%).

**Table (10).** Standard physiologic races, and virulent formulas originated from 30 isolates of *P. graminis tritici* on 17 stem rust monogenic lines in Egypt during the growing season of 1998/1999.

| Egyptian stem rust isolates | Standard physiologic races | Avirulence/virulence formulae | Number of isolates | Frequency (%) |
|---|---|---|---|---|
| ES* 11*-1*** | 11 | 26,$Gt^+$ | 2 | 6.66 |
| ES 11-2 | 11 | 8a,9e,26 | 1 | 3.33 |
| ES 11-3 | 11 | 9e,26,36,$Gt^+$ | 2 | 6.66 |
| ES 11-4 | 11 | 9e,26,30,$Gt^+$ | 1 | 3.33 |
| ES 11-5 | 11 | 9e,26,27,$Gt^+$ | 1 | 3.33 |
| ES 11-6 | 11 | 7b,9e,26,$Gt^+$ | 1 | 3.33 |
| ES 11-7 | 11 | 5,8a,9e,11,26,30 | 1 | 3.33 |
| ES 11-8 | 11 | 9b,9e,11,26,27,$Gt^+$ | 1 | 3.33 |
| ES 11-9 | 11 | 6,7b,9b,9e,11,26,36 | 1 | 3.33 |
| ES 11-10 | 11 | 5,7b,8a,9b, 9e,26,30,$Gt^+$ | 1 | 3.33 |
| ES 14-11 | 14 | 6,8a,9b, 9e,26,30 | 1 | 3.33 |
| ES 14-12 | 14 | 5,6,7b,8a,9e,11,26,30,36 | 1 | 3.33 |
| ES 15-13 | 15 | 5 | 1 | 3.33 |
| ES 15-14 | 15 | 7b,36 | 1 | 3.33 |
| ES 15-15 | 15 | 26,$Gt^+$ | 1 | 3.33 |
| ES 15-16 | 15 | 7b,26,27 | 1 | 3.33 |

Table (10). Cont.

| Egyptian stem rust isolates | Standard physiologic races | Avirulence/virulence formulae | Number of isolates | Frequency (%) |
|---|---|---|---|---|
| ES* 17*-17*** | 17 | 9e,26 | 1 | 3.33 |
| ES 17-18 | 17 | 6,9e,26 | 1 | 3.33 |
| ES 17-19 | 17 | 6,8a,9e,21,26,30 | 1 | 3.33 |
| ES 17-20 | 17 | 5,6,7b,8a,9e,11,26,30 | 1 | 3.33 |
| ES 19-21 | 19 | 8a,9e,36 | 1 | 3.33 |
| ES 19-22 | 19 | 5,9e,30,36 | 1 | 3.33 |
| ES 19-23 | 19 | 6,7b,9b,9e,11,27,29 | 1 | 3.33 |
| ES 19-24 | 19 | 5,8a,9b,9e,11,17,26,30,36 | 1 | 3.33 |
| ES 19-25 | 19 | 5,6,8a,9e,9g,11,17,26,29,30 | 1 | 3.33 |
| ES 39-26 | 39 | 8a,26 | 1 | 3.33 |
| ES 39-26 | 39 | 9e,26,36 | 1 | 3.33 |
| ES 39-26 | 39 | 7b,8a,9e,11,26 | 1 | 3.33 |

* = Egyptian stem rust.
* = Standard physiologic race.
*** = serial number of single pustule.

**Table (11).** Efficacy (%) and virulence ratios of 17 *Sr*'s evaluated against 30 isolates of *P. graminis tritici* in Egypt during the growing season of 1998/1999.

| No. | *Sr*'s | No. of resistant response | No. of susceptible responses | Efficacy (%) | Virulence ratios |
|---|---|---|---|---|---|
| 1 | *Sr* 5 | 8 | 22 | 26.67 | 73.33 |
| 2 | 6 | 8 | 22 | 26.67 | 73.33 |
| 3 | 7b | 9 | 21 | 30.00 | 70.00 |
| 4 | 8a | 12 | 18 | 40.00 | 60.00 |
| 5 | 9b | 6 | 24 | 20.00 | 80.00 |
| 6 | 9d | 0 | 30 | 0.00 | 100 |
| 7 | 9e | 23 | 7 | 76.67 | 23.33 |
| 8 | 9g | 1 | 29 | 3.33 | 96.67 |
| 9 | 11 | 9 | 21 | 30.00 | 70.00 |
| 10 | 17 | 2 | 28 | 6.67 | 93.33 |
| 11 | 21 | 1 | 29 | 3.33 | 96.67 |
| 12 | 26 | 25 | 5 | 83.33 | 16.67 |
| 13 | 27 | 4 | 26 | 13.33 | 86.67 |
| 14 | 29 | 2 | 28 | 6.67 | 93.33 |
| 15 | 30 | 10 | 20 | 33.33 | 66.67 |
| 16 | 36 | 9 | 21 | 30.00 | 70.00 |
| 17 | $Gt^{+}$ | 10 | 20 | 33.33 | 66.67 |

Data presented in Table (12) revealed the virulence formulas of 4 physiologic races originated from 30 single pustules (*P. graminis tritici*) identified on 18 stem rust wheat monognic lines (*Sr*'s).

These data indicated that each of the isolates has the same frequency since each was frequent once. Races *i.e.* ES11-1, ES 11-2 and ES 15-21 exhibited the highest level of virulence since they were virulent to 16 *Sr*'s out of 18. On the other hand, races ES 11-20 and ES 15-28 exhibited the lowest level of virulence, since they attack 9 out of 18 *Sr*'s.

Regarding the gene efficacy against stem rust isolates during 1999/2000, data presented in Table (13) indicated that *Sr* $T_{t-1}$ was the most effective one (86.67%) followed by *Sr* 11 (70%), 9e (66.67%) *Sr* 21 (63.33%). The rest of genes ranged between (3.33% and 46.67%). *Sr*'s 9b and 9d exhibited 100 virulence ratio since they attacked all the tested isolates.

**Table (12).** Standard physiologic races, and virulent formulas originated from 30 isolates of *P. graminis tritici* on 17 stem rust monogenic lines in Egypt during the growing season of 99/2000.

| Egyptian stem rust isolates | Standard physiologic races | Avirulence/virulence formulae | Number of isolates | Frequency (%) |
|---|---|---|---|---|
| ES* 11*-1*** | 11 | 11,21 | 1 | 3.33 |
| ES 11-2 | 11 | 9e,11 | 1 | 3.33 |
| ES 11-3 | 11 | 11,26,$T_{t-1}$ | 1 | 3.33 |
| ES 11-4 | 11 | 9e,11,21 | 1 | 3.33 |
| ES 11-5 | 11 | 9g,21,$T_{t-1}$ | 1 | 3.33 |
| ES 11-6 | 11 | 9e,11,26,$T_{t-1}$ | 1 | 3.33 |
| ES 11-7 | 11 | 21,26,$Gt^{+}$,$T_{t-1}$ | 1 | 3.33 |
| ES 11-8 | 11 | 11,17,21,27 | 1 | 3.33 |
| ES 11-9 | 11 | 9e,21,$Gt^{+}$,$T_{t-1}$ | 1 | 3.33 |
| ES 11-10 | 11 | 6,9e,26,$Gt^{+}$,$T_{t-1}$ | 1 | 3.33 |
| ES 11-11 | 11 | 6,9e,11,26,$T_{t-1}$ | 1 | 3.33 |
| ES 11-12 | 11 | 9e,11,26,$Gt^{+}$,$T_{t-1}$ | 1 | 3.33 |
| ES 11-13 | 11 | 9e,11,21,26,$T_{t-1}$ | 1 | 3.33 |
| ES 11-14 | 11 | 9e,17,21,$Gt^{+}$,$T_{t-1}$ | 1 | 3.33 |
| ES 11-15 | 11 | 6,9e,11,21,26,$T_{t-1}$ | 1 | 3.33 |
| ES 11-16 | 11 | 6,9e,11,26,$Gt^{+}$,$T_{t-1}$ | 1 | 3.33 |
| ES 11-17 | 11 | 7b,21,27,29,30,$Gt^{+}$,$T_{t-1}$ | 1 | 3.33 |

Table (12). Cont.

| Egyptian stem rust isolates | Standard physiologic races | Avirulence/virulence formulae | Number of isolates | Frequency % |
|---|---|---|---|---|
| ES* 11*-18*** | 11 | 9e,11,21,27,30,$Gt^+$,$T_{t-1}$ | 1 | 3.33 |
| ES 11-19 | 11 | 6,9d,11,17,21,26,$Gt^+$,$T_{t-1}$ | 1 | 3.33 |
| ES 11-20 | 11 | 5,6,7b,8a,11,12,26,$Gt^+$,$T_{t-1}$ | 1 | 3.33 |
| ES 15-21 | 15 | 9e,$T_{t-1}$ | 1 | 3.33 |
| ES 15-22 | 15 | 5,21,29,$T_{t-1}$ | 1 | 3.33 |
| ES 15-23 | 15 | 6,9e,11,26,$T_{t-1}$ | 1 | 3.33 |
| ES 15-24 | 15 | 9e,11,26,$Gt^+$,$T_{t-1}$ | 1 | 3.33 |
| ES 15-25 | 15 | 5,11,21,29,30,36,$T_{t-1}$ | 1 | 3.33 |
| ES 15-26 | 15 | 5,9g,17,21,26,27,$T_{t-1}$ | 1 | 3.33 |
| ES 15-27 | 15 | 6,9e,11,21,26,$Gt^+$,$T_{t-1}$ | 1 | 3.33 |
| ES 15-28 | 15 | 9e,9g,11,21,29,30,36,$Gt^+$,$T_{t-1}$ | 1 | 3.33 |
| ES 17-29 | 17 | 9e,9g,11,21,26,$T_{t-1}$ | 1 | 3.33 |
| ES 39-30 | 39 | 9e,11,26,$Gt^+$,$T_{t-1}$ | 1 | 3.33 |

* = Egyptian stem rust.
* = Standard physiologic race.
*** = serial number of single pustule.

**Table (13).** Efficacy (%) and virulence ratios of 18 *Sr*'s evaluated against 30 isolates of *P. graminis tritici* in Egypt during the growing season of 1999/2000.

| No. | *Sr*'s | No. of resistant responses | No. of susceptible responses | Efficacy (%) | Virulence ratios |
|---|---|---|---|---|---|
| 1 | *Sr* 5 | 3 | 27 | 10.0 | 90.0 |
| 2 | 6 | 8 | 22 | 26.67 | 73.33 |
| 3 | 7b | 2 | 28 | 6.67 | 93.33 |
| 4 | 8a | 1 | 29 | 3.33 | 96.66 |
| 5 | 9b | 0 | 30 | 0.00 | 100.00 |
| 6 | 9d | 0 | 30 | 0.00 | 100.00 |
| 7 | 9e | 20 | 10 | 66.67 | 33.33 |
| 8 | 9g | 4 | 26 | 13.33 | 86.67 |
| 9 | 11 | 21 | 9 | 70.00 | 30.00 |
| 10 | 17 | 4 | 26 | 13.33 | 86.67 |
| 11 | 21 | 19 | 11 | 63.33 | 36.67 |
| 12 | 26 | 17 | 13 | 56.67 | 43.33 |
| 13 | 27 | 4 | 26 | 13.33 | 86.67 |
| 14 | 29 | 4 | 26 | 13.33 | 86.67 |
| 15 | 30 | 4 | 26 | 13.33 | 86.67 |
| 16 | 36 | 1 | 29 | 3.33 | 96.67 |
| 17 | $Gt^{+}$ | 14 | 16 | 46.67 | 53.33 |
| 18 | $T_{t-1}$ | 26 | 4 | 86.67 | 13.33 |

**The recent race nomenclature system:**

As regard to the distribution of resistance genes according to the new nomenclature system adopted by **Roelfs & Marten (1988).** These data revealed the presence of 30 different isolates on the basis of their reaction on 12 isogenic lines. in Table (14) the presented data indicated that *Sr* 9e (76.7%) was the more frequent gene to which the isolates were avirulent, followed by *Sr* 8a (40.00%) which was involved in less frequent isolates. On the other hand, *Sr* 7b and *Sr* 30 were distributed at the same frequency (36.6%).

This result confirmed to some extent the effectiveness of *Sr* 9e, 8a, *Sr* 7b, *Sr* 30, and *Sr* 36 against stem rust uredospore populations during the season.

Data presented in Table (15) revealed identification of physiologic races of *Puccinia graminis tritici* from the perspective of using stem rust near isogenic lines in relation to the previous designation. These data indicated that during 1998/1999 races *i.e.* RTK, TTT were the most frequent ones (10%), followed by RTT (6.6%) of the total number. The rest were represented by (3.3%) for each.

It could be concluded from these data that TTT was virulent to all of the near isogenic lines tested, However RTK and RTT were avirulent to (9e, 36), 9e, respectively, Table (14) and (15).

**Table (14):** The infection types (L = Low and H = High) produced by selected races of *Puccinia graminis f. sp. tritici* from North Governorates of Egypt on host with the resistance genes in the Pgt differential set during 1998/1999 growing season.

| No. | Pgt code | *Sr* genes sets | | | | | | | | | | | | Race* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Set I | | | | Set II | | | | Set III | | | | |
| | | 5 | 21 | 9e | 7b | 11 | 6 | 8a | 9 g | 36 | 9b | 30 | 17 | |
| 1 | BBG | L | L | L | L | L | L | L | L | L | | L | L | 19 |
| 2 | GCH | L | | L | L | L | L | L | | L | | L | | 14 |
| 3 | GCR | L | | L | L | L | L | L | | | | L | | 17 |
| 4 | GRM | L | | L | L | | | L | | | L | L | | 11 |
| 5 | HHB | L | | L | | L | | L | | L | L | L | L | 19 |
| 6 | HHR | L | | L | | L | | L | | | | L | | 11 |
| 7 | KTT | L | | | | | | | | | | | | 15 |
| 8 | MMR | | L | L | | | L | L | | | | L | | 17 |
| 9 | NTN | L | | L | | | | | | L | | L | | 19 |
| 10 | QFF | | | L | L | L | L | | | L | L | | | 11 |
| 11 | QFP | | | L | L | L | L | | | | L | | | 19 |
| 12 | QHT | | | L | L | L | | L | | | | | | 39 |
| 13 | QTT | | | L | L | | | | | | | | | 11 |
| 14 | RKP | | | L | | L | | | | | L | | | 11 |
| 15 | RMM | | | L | L | | L | L | | | L | L | | 14 |

**Table (14):** Cont.

| No. | Pgt code | *Sr* genes sets | | | | | | | | | | | | Race* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Set I | | | | Set II | | | | Set III | | | | |
| | | 5 | 21 | 9e | 7b | 11 | 6 | 8a | 9 g | 36 | 9b | 30 | 17 | |
| 16 | RPR | | | L | | | L | | | | | L | | 17 |
| 17 | RRK | | | L | | | | L | | L | | | | 19 |
| 18 | RRT | | | L | | | | L | | | | | | 11 |
| 19 | RTK | | | L | | | | | | L | | | | 11 |
| 20 | RTK | | | L | | | | | | L | | | | 11 |
| 21 | RTK | | | L | | | | | | L | | | | 39 |
| 22 | RTR | | | L | | | | | | | | L | | 11 |
| 23 | RTT | | | L | | | | | | | | | | 17 |
| 24 | RTT | | | L | | | | | | | | | | 11 |
| 25 | STK | | | | L | | | | | L | | | | 15 |
| 26 | STT | | | | L | | | | | | | | | 15 |
| 27 | TRT | | | | | | | L | | | | | | 39 |
| 28 | TTT | | | | | | | | | | | | | 15 |
| 29 | TTT | | | | | | | | | | | | | 11 |
| 30 | TTT | | | | | | | | | | | | | 11 |
| **Total number of isolates** | | 8 | 2 | 23 | 11 | 9 | 8 | 12 | 1 | 10 | 6 | 11 | 2 | - |
| **Frequency %** | | 27 | 6.6 | 76.7 | 36.6 | 30 | 26.6 | 40 | 3.1 | 33.3 | 20 | 36.6 | 6.6 | - |

☐ Plank = High infection type.

* According to the traditional method of **Stakman *et al.* (1962)**.

**Table (15).** Physiologic races identified from 30 isolates of *Puccinia graminis tritici* and their frequency (%) in Egypt during the growing season 1998/1999*.

| No. | Pgt-code | Number of isolates | Frequency (%) |
|---|---|---|---|
| 1 | BBG | 1 | 3.33 |
| 2 | GCH | 1 | 3.33 |
| 3 | GCR | 1 | 3.33 |
| 4 | GRM | 1 | 3.33 |
| 5 | HHB | 1 | 3.33 |
| 6 | HHR | 1 | 3.33 |
| 7 | KTT | 1 | 3.33 |
| 8 | MMR | 1 | 3.33 |
| 9 | NTN | 1 | 3.33 |
| 10 | QFF | 1 | 3.33 |
| 11 | QFP | 1 | 3.33 |
| 12 | QHT | 1 | 3.33 |
| 13 | QTT | 1 | 3.33 |
| 14 | RKP | 1 | 3.33 |
| 15 | RMM | 1 | 3.33 |
| 16 | RPR | 1 | 3.33 |
| 17 | RRK | 1 | 3.33 |
| 18 | RRT | 1 | 3.33 |
| 19 | RTK | 3 | 10.00 |
| 20 | RTR | 1 | 3.33 |
| 21 | RTT | 2 | 6.66 |
| 22 | STK | 1 | 3.33 |
| 23 | STT | 1 | 3.33 |
| 24 | TRT | 1 | 3.33 |
| 25 | TTT | 3 | 10.00 |
| Total | | 30 | 100.00 |

* The nomenclature was carried out following the method adopted by **Roelfs and Martens (1988).**

Regarding the distribution of such genes within the resultant physiologic races Table (16), the presented data indicated that *Sr* 9e (73.3%) occupied the first rank followed by *Sr* 11 (73.3%), *Sr* 21 (66.6%), *Sr* 6 (26.6%), *Sr* 17, *Sr* 5 (13.3%) and *Sr* 9g, *Sr* 30 (10%) respectively. The rest of genes were represented by (3.3%).

It was noticed that either of the tested isolates was virulent to *Sr* 9b.

Data presented in Table (17) revealed the designation of the physiologic races according to the new nomenclature system adopted by **Roelfs & Marten (1988)** during the growing season of 1999/2000. The most frequent one was RKT (16.6%) followed by RFT (10%), MKT (10%) and MFT (6.6%). The rest of isolates were represented by (3.3%) each.

It could be concluded from these data that RKT, RFT, MKT and MFT were avirulent to (*Sr* 9e, *Sr* 11); (*Sr* 9e, *Sr* 11, *Sr* 6); (*Sr* 21, *Sr* 9e, *Sr* 11) and (*Sr* 21, *Sr* 9e, *Sr* 11, *Sr* 6) respectively, Table (16) and (17).

**Table (16 ):** The infection types (L = Low and H = High) produced by selected races of *Puccinia graminis f. sp. tritici* from North Governorates of Egypt on host with the resistance genes in the Pgt differential set during 99/2000 growing season.

| No. | Pgt code | *Sr* genes sets | | | | | | | | | | | | Race* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Set I | | | | Set II | | | | Set III | | | | |
| | | 5 | 21 | 9e | 7b | 11 | 6 | 8a | 9 g | 36 | 9b | 30 | 17 | |
| 1 | DCT | L | L | | | L | L | L | | | | | | 11 |
| 2 | FKR | L | L | | | L | | | | | | L | | 15 |
| 3 | FSS | L | L | | | | | | L | | | | L | 15 |
| 4 | FTT | L | L | | | | | | | | | | | 15 |
| 5 | MFS | | L | L | | L | L | | | | | | L | 11 |
| 6 | MFT | | L | L | | L | L | | | | | | | 11 |
| 7 | MFT | | L | L | | L | L | | | | | | | 15 |
| 8 | MJH | | L | L | | | | | | L | | L | | 15 |
| 9 | MJR | | L | L | | L | | | | | | L | | 11 |
| 10 | MJT | | L | L | | L | | | L | | | | | 17 |
| 11 | MKS | | L | L | | L | | | | | | | L | 11 |
| 12 | MKT | | L | L | | L | | | | | | | | 11 |
| 13 | MKT | | L | L | | L | | | | | | | | 11 |
| 14 | MKT | | L | L | | L | | | | | | | | 11 |
| 15 | MTT | | L | L | | | | | | | | | | 11 |

Table (16). Cont.

| No. | Pgt code | *Sr* genes sets | | | | | | | | | | | | Race* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 21 | 9e | 7b | 11 | 6 | 8a | 9 g | 36 | 9b | 30 | 17 | |
| 16 | PKS | | L | | | L | | | | | | | L | 11 |
| 17 | PKT | | L | | | L | | | | | | | | 11 |
| 18 | PST | | L | | | | | | L | | | | | 11 |
| 19 | PTT | | | L | | | | | | | | | | 11 |
| 20 | RFT | | L | L | | L | L | | | | | | | 11 |
| 21 | RFT | | L | L | | L | L | | | | | | | 11 |
| 22 | RFT | | L | L | | L | L | | | | | | | 15 |
| 23 | RJT | | | L | | L | | | | | | | | 11 |
| 24 | RKT | | | L | | L | | | | | | | | 11 |
| 25 | RKT | | | L | | L | | | | | | | | 11 |
| 26 | RKT | | | L | | L | | | | | | | | 15 |
| 27 | RKT | | | L | | L | | | | | | | | 39 |
| 28 | RKT | | | L | | L | | | | | | | | 39 |
| 29 | RPT | | | L | | | L | | | | | | | 11 |
| 30 | RTR | | | L | | | | | | | | | | 15 |
| **Total number of isolates** | | 4 | 20 | 23 | 0 | 22 | 8 | 1 | 3 | 1 | 0 | 3 | 4 | - |
| **Frequency %** | | 13.3 | 66.6 | 73.3 | 0 | 73.3 | 26.6 | 3.3 | 10 | 3.3 | 0 | 10 | 13.3 | - |

Plank = High infection type.

* According to the traditional method of **Stakman *et al.* (1962)**.

**Table (17).** Physiologic races identified from 30 isolates of *Puccinia graminis tritici* and their frequency (%) in Egypt during the growing season 99/2000*.

| No. | Pgt-code | Number of isolates | Frequency (%) |
|---|---|---|---|
| 1 | DCT | 1 | 3.33 |
| 2 | FKR | 1 | 3.33 |
| 3 | FSS | 1 | 3.33 |
| 4 | FTT | 1 | 3.33 |
| 5 | MFS | 1 | 3.33 |
| 6 | MFT | 2 | 6.66 |
| 7 | MJH | 1 | 3.33 |
| 8 | MJR | 1 | 3.33 |
| 9 | MJT | 1 | 3.33 |
| 10 | MKS | 1 | 3.33 |
| 11 | MKT | 3 | 10.00 |
| 12 | MTT | 1 | 3.33 |
| 13 | PKS | 1 | 3.33 |
| 14 | PKT | 1 | 3.33 |
| 15 | PST | 1 | 3.33 |
| 16 | PTT | 1 | 3.33 |
| 17 | RFT | 3 | 10.00 |
| 18 | RJT | 1 | 3.33 |
| 19 | RKT | 5 | 16.66 |
| 20 | RPT | 1 | 3.33 |
| 21 | RTT | 1 | 3.33 |
| Total | | 30 | 100.00 |

* The nomenclature was carried out following the method adopted by **Roelfs and Martens (1988).**

**Probable genes for stem rust resistance:**

Data presented in Table (18) revealed matching of 16 monogenic lines and 20 commercial wheat varieties against 30 isolates of stem rust pathogen (*P. graminis tritici*). These data indicated presence of low infection type: high infection type in the (commercials : monogenic) indicating the inclusion of the *Sr* within the genetic make up of the commercial cultivar. This was assigned by the symbol (0).

Other group of comparisons showed the presence of low infection type: high infection type and high infection type: low infection types between the commercials and monogenics against the tested isolates and this would indicate that each of the vars. may have gene(s) not involved in the other. It was assigned by the symbol (+). Certain group showed low infection types within the monogenics, however the commercials exhibited high infection type in the matching against the isolates. This would indicate the absence of such gene (s) within the commercials, and would assigned by the symbol (-).

Data in Table (19) revealed probable resistance genes may be presented in the genetic back ground of certain commercial varieties as derived from the last table. These data indicated that cultivar Sakha 61 included the least number of stem rust resistant genes *i.e.* (3) followed by Giza 160 (4). On the other hand, Gemmeiza-7 exhibited the highest number of genes *i.e.* 13 followed by Giza 167 (11) and Sohag-1 (11) the rest of cultivars included between 5 and 10 resistant genes.

**Table (18).** Comparison of incidence of low infection type : high infection type (R:S) on each of monogenic lines and varieties inoculated with 30 isolates of *Puccinia graminis* f. sp. *tritici*.

| Variety (A) | Host monogenic lines (B) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Sr* 5 | *Sr* 6 | *Sr* 7b | *Sr* 8a | *Sr* 9e | *Sr* 9g | *Sr* 11 | *Sr* 17 | *Sr* 21 | *Sr* 26 | *Sr* 27 | *Sr* 29 | *Sr* 30 | *Sr* 36 | *Sr* Gt | *Sr* $t_{r1}$ |
| **Sids 1** | + | + | + | + | + | + | + | + | + | - | 0 | 0 | 0 | 0 | + | + |
| **Sids 6** | + | + | 0 | 0 | + | + | + | + | + | + | + | 0 | 0 | 0 | + | + |
| **Sids 7** | 0 | 0 | 0 | 0 | + | + | + | + | + | + | + | 0 | 0 | 0 | + | + |
| **Sids 8** | + | + | 0 | 0 | + | + | + | + | + | + | + | 0 | 0 | 0 | + | + |
| **Sids 9** | + | + | 0 | 0 | + | + | + | + | + | - | + | 0 | 0 | 0 | + | + |
| **Giza 160** | + | + | + | + | + | + | + | + | + | - | 0 | 0 | 0 | 0 | + | + |
| **Giza 164** | + | 0 | 0 | 0 | + | + | + | + | + | + | + | 0 | 0 | 0 | + | + |
| **Giza 165** | 0 | + | 0 | 0 | + | 0 | 0 | + | 0 | + | 0 | 0 | 0 | 0 | + | + |
| **Giza 167** | 0 | 0 | 0 | 0 | + | 0 | + | 0 | + | + | 0 | 0 | 0 | 0 | 0 | + |
| **Giza 168** | + | 0 | 0 | 0 | + | + | + | + | + | - | + | 0 | 0 | 0 | + | + |
| **Sakha 8** | + | + | 0 | 0 | + | + | + | + | - | - | + | 0 | 0 | 0 | + | + |
| **Sakha 61** | + | + | + | 0 | + | + | + | + | + | + | + | + | + | 0 | 0 | + |
| **Sakha 69** | + | + | 0 | 0 | + | + | + | + | + | + | + | 0 | 0 | 0 | + | + |
| **Sakha 202** | + | + | 0 | 0 | + | + | + | + | + | + | + | 0 | 0 | 0 | 0 | + |
| **Gemmeiza 3** | + | + | 0 | 0 | + | + | + | + | + | + | + | 0 | 0 | 0 | 0 | + |
| **Gemmiza 5** | + | + | 0 | 0 | + | + | + | + | + | + | + | 0 | 0 | 0 | + | + |
| **Gemmeiza 7** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | + | + | 0 | + | 0 | 0 | 0 | 0 | 0 |
| **Sohag 1** | 0 | + | 0 | 0 | + | 0 | + | 0 | + | + | 0 | 0 | 0 | 0 | 0 | + |
| **Sohag 3** | + | + | + | + | + | + | + | + | + | + | + | 0 | 0 | 0 | + | + |
| **Bani Sweif** | + | + | 0 | 0 | + | + | + | + | + | - | + | 0 | 0 | 0 | + | + |

0 = Host B has the same gene (s) as in the host AA and additional genes.
+ = Hosts A and B do not carry the same resistance genes.
- = Host B does not contain the resistance gene in host A.

**Table (19).** Probable resistance genes for stem rust in some Egyptian wheat entries.

| No. | Wheat entries | Probable *Sr* genes | Total number of *Sr* genes |
|---|---|---|---|
| 1 | Gemmeiza-3 | 7b, 8a, 29, 30, 36, $Gt^+$ | 6 |
| 2 | Gemmeiza-7 | 5, 6, 7b, 8a, 9e, 9g, 11, 26, 29, 30, 36, $Gt^+$, $T_{t-1}$ | 13 |
| 3 | Gemmeiza-5 | 7b, 8a, 29, 30, 36 | 5 |
| 4 | Giza 160 | 27, 29, 30, 36 | 4 |
| 5 | Giza 164 | 6, 7b, 8a, 29, 30, 36 | 6 |
| 6 | Giza 165 | 5, 7b, 8a, 9, 11, 21, 27, 29, 30, 36 | 10 |
| 7 | Giza 167 | 5, 6, 7b, 8a, 9g, 17, 27, 29, 30, 36, $Gt^+$ | 11 |
| 8 | Giza 168 | 6, 7b, 8a, 29, 30, 36 | 6 |
| 9 | Sakha 202 | 7b, 8a, 29, 30, 36, $Gt^+$ | 6 |
| 10 | Sakha 61 | 8a, 36, $Gt^+$ | 3 |
| 11 | Sakha 69 | 7b, 8a, 29, 30, 36 | 5 |
| 12 | Sakha 8 | 7b, 8a, 29, 30, 36 | 5 |
| 13 | Sids-1 | 27, 29, 30, 36 | 4 |
| 14 | Sids-6 | 7b, 8a, 29, 30, 36 | 5 |
| 15 | Sids-7 | 5, 6, 7, 8a, 29, 30, 36 | 7 |
| 16 | Sids-8 | 7b, 8a, 29, 30, 36 | 5 |
| 17 | Sids-9 | 7b, 8a, 29, 30, 36 | 5 |
| 18 | Beni Sweif-1 | 7b, 8a, 29, 30, 36 | 5 |
| 19 | Sohag-1 | 5, 7b, 8a, 9g, 17, 27, 29, 30, 36, $Gt^+$ | 10 |
| 20 | Sohag-3 | 29, 30, 36 | 3 |

As regard to the distribution of stem rust resistant genes within commercial cultivars, data presented in Table (20) revealed that *Sr* 36 is the most common gene within the Egyptian commercials, *i.e.* (20 var.) followed by *Sr* 29 and *Sr* 30 (95%), 8a (80%) and 7b (80%). The rest of resistance genes ranged between 5% and 30%.

**Table (20).** Probable resistance genes for stem rust in some Egyptian wheat entries.

| No. | *Sr* genes | Total number of Egypt comm. vars. | Frequency (%) |
|---|---|---|---|
| 1 | *Sr* 5 | 5 | 25 |
| 2 | *Sr* 6 | 5 | 25 |
| 3 | *Sr* 7b | 16 | 80 |
| 4 | *Sr* 8a | 16 | 80 |
| 5 | *Sr* 9e | 1 | 5 |
| 6 | *Sr* 9 | 4 | 20 |
| 7 | *Sr* 11 | 2 | 10 |
| 8 | *Sr* 17 | 2 | 10 |
| 9 | *Sr* 21 | 1 | 5 |
| 10. | *Sr* 26 | 1 | 5 |
| 11 | *Sr* 27 | 4 | 20 |
| 12 | *Sr* 29 | 19 | 95 |
| 13 | *Sr* 30 | 19 | 95 |
| 14 | *Sr* 36 | 20 | 100 |
| 15 | *Sr* $Gt^{+}$ | 6 | 30 |
| 16 | *Sr* $T_{t-1}$ | 1 | 5 |

**II. Labratorial experiments including :**

**A. Components of partial resistance in certain local wheat entries:**

This experiment was directed to study the components of partial resistance in certain local wheat entries, expressed in the reaction type against two physiologic races *i.e.* race no. 11 and race no. 15, at seedling stage likewise number of erupted and non-erupted pustules, area of both colony and pustule and latent period also was determined.

Data presented in Table (21) show reaction of 14 wheat entries against two stem rust (*P. graminis tritici*) physiologic races. These data indicated that 8 out of 14 entries showed susceptibility to race no. 11, however the rest showed moderate susceptible response. Regarding race no. 15 only 3 entries were susceptible, 6 were moderate susceptible and 5 were moderate resistant. Therefore it could conclude that race 11 is more virulent than race 15.

Data in Table (22) revealed response of the tested entries toward 2 components of partial resistance *i.e.* erupted, non-erupted pustules and latent period against the two tested races. These data indicate presence of significant differences between entries against race 11 in the number of erupted pustules. The number of erupted pustules was recorded with Little Club (31.0) followed by Sakha 8 (29.0) and Giza 160 (26.7). On the other hand, the least eruption was recorded with Gemmeiza-5 and Giza 168 (18.0), Gemmeiza-1 (18.7) and Gemmeiza-7 (19.0). The rest of test entries lied in between.

Concerning the number of non-erupted pustules the situation was quite different, since no significance was detected between 6 entries. Regarding the eruption percent for each entry, data presented in Table (22) indicated that two entries *i.e.* Little Club and Sakha 8 exhibited the highest ratio of uredosori eruption, however the reverse was notices with entries Gemmeiza-7 and Gemmeiza-5 when all were inoculated with race no. 11.

The situation was quite different as race no. 15 was used for inoculation, since the highest uredosori eruption percent was recorded again with Little Club and Sakha 8. But the lowest ratio was recorded with Gemmeiza-9 and Giza 168.

**Table (21).** Response of Egyptian commercial wheat varieties (seedling reaction) to the most prevalence physiologic races of *Puccinia graminis* f. *tritici* (race 11 and race 15), under greenhouse conditions.

| No. | Wheat entries | Physiologic race of Stem rust reaction* | |
|---|---|---|---|
| | | Race 11 | Race 15 |
| 1 | Gemmeiza-1 | 4 | 3 |
| 2 | Gemmeiza-5 | 4 | 3 |
| 3 | Gemmeiza-7 | 3 | 2 |
| 4 | Gemmeiza-9 | 3 | 2 |
| 5 | Giza 160 | 4 | 4 |
| 6 | Giza 163 | 3 | 2 |
| 7 | Giza 164 | 3 | 2 |
| 8 | Giza 167 | 3 | 3 |
| 9 | Giza 168 | 3 | 2 |
| 10 | Sakha 8 | 4 | 4 |
| 11 | Sakha 61 | 4 | 3 |
| 12 | Sakha 93 | 4 | 3 |
| 13 | Sakha 202 | 4 | 3 |
| 14 | Little Club | 4 | 4 |

* Infection type according to Stakman *et al.* (1962)

The highest number of non-erupted pustules was observed with Gemmeiza-7 followed by Sakha 61, Giza 163 and Gemmeiza-9. The rest of entries showed the lowest values in this respect.

The present data, also revealed that the highest latent period was recorded with Gemmeiza-9 followed by Giza 164, however the reverse was noticed with entries *i.e.* Giza 160, Giza 168, Sakha 8, and Little Club. This was the situation with race 11. As regard to the evaluation against race 15, the trend was a little bet similar, since most of the tested entries were significantly differentiated regarding the eruption of pustules. Little Club, Sakha 8 and Giza 160 exhibited the highest values of eruption, while Giza 168, Gemmeiza-7 and Gemmeiza-5 exhibited relatively lower values of eruption. Gemmeiza-9 exhibited the lowest value of pustule eruption.

As for non-erupted pustules, the presented data in the table indicate distinction of Gemmeiza-9 followed by both Giza 168 and Sakha 93. On the other hand, no significance could be detected between Gemm.-1, Gemm.-5, Giza 167 and Little Club which exhibited the least value of non-eruption, and between Giza 160 and Sakha 8.

Concerning the latent period the entries *i.e.* Gemm.-9, Giza 164, Sakha 93 and Sakha 202 exhibited the longest latent period, and were significantly different from the other entries. The least latent period was recorded with Little Club.

**Table (22).** Mean number of erupted, non-erupted pustules/cm$^2$, total pustules, erupted ratio and latent period (in days) of *Puccinia graimins* f. sp. *tritici* on the first leaf of 14 wheat cultivars under greenhouse condition.

| Wheat cntries | Physiologic races | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Race 11 | | | | | Race 15 | | | | |
| | Eru. pus. | Non -eru. pus | Total pus. | Eru. pus. (%) | L.P * | Eru. pus. | Non -eru. pus | Total pus. | Eru. pus. (%) | L.P * |
| Gemmeiza-1 | 18.7$^{k}$ | 1.6$^{e}$ | 20.3 | 92.1 | 9$^{e}$ | 15.0$^{f}$ | 1.3$^{h}$ | 16.3 | 92.0 | 10$^{c}$ |
| Gemmeiza-5 | 18.0$^{l}$ | 2.3$^{c}$ | 20.3 | 88.7 | 9$^{e}$ | 13.0$^{g}$ | 1.3$^{h}$ | 14.3 | 90.9 | 12$^{c}$ |
| Gemmeiza-7 | 19.0$^{j}$ | 6.0$^{a}$ | 25.0 | 76.0 | 12$^{c}$ | 12.0$^{h}$ | 1.8$^{g}$ | 13.8 | 86.9 | 12$^{c}$ |
| Gemmeiza-9 | 19.8$^{i}$ | 2.0$^{d}$ | 21.8 | 90.8 | 14$^{a}$ | 11.0$^{j}$ | 4.6$^{a}$ | 15.6 | 70.5 | 14$^{a}$ |
| Giza 160 | 26.7$^{c}$ | 1.3$^{g}$ | 28.0 | 95.4 | 7$^{f}$ | 19.0$^{b}$ | 1.2$^{i}$ | 20.2 | 94.0 | 8$^{g}$ |
| Giza 163 | 25.0$^{e}$ | 2.3$^{c}$ | 27.3 | 91.6 | 9$^{e}$ | 13.0$^{g}$ | 2.0$^{f}$ | 15.0 | 86.7 | 9$^{f}$ |
| Giza 164 | 22.0$^{g}$ | 1.4$^{f}$ | 23.4 | 94.0 | 13$^{b}$ | 18.0$^{c}$ | 4.0$^{c}$ | 22.0 | 81.8 | 14$^{a}$ |
| Giza 167 | 22.0$^{g}$ | 1.3$^{g}$ | 23.3 | 94.4 | 9$^{e}$ | 18.0$^{c}$ | 1.3$^{h}$ | 19.3 | 93.3 | 9$^{f}$ |
| Giza 168 | 18.0$^{l}$ | 1.3$^{g}$ | 19.3 | 93.3 | 7$^{f}$ | 11.3$^{i}$ | 4.3$^{b}$ | 15.6 | 72.4 | 11$^{d}$ |
| Sakha 8 | 29.0$^{b}$ | 1.2$^{h}$ | 30.2 | 96.0 | 7$^{f}$ | 19.0$^{b}$ | 1.3$^{h}$ | 20.3 | 93.6 | 8$^{g}$ |
| Sakha 61 | 25.7$^{d}$ | 2.6$^{b}$ | 28.3 | 90.8 | 9$^{e}$ | 15.0$^{f}$ | 3.3$^{d}$ | 18.3 | 81.9 | 10$^{e}$ |
| Sakha 93 | 21.3$^{h}$ | 1.6$^{e}$ | 22.9 | 93.0 | 10$^{d}$ | 15.7$^{e}$ | 4.3$^{b}$ | 20.0 | 78.5 | 14$^{a}$ |
| Sakha 202 | 23.0$^{f}$ | 2.3$^{c}$ | 25.3 | 90.9 | 9$^{e}$ | 16.0$^{d}$ | 2.3$^{c}$ | 18.3 | 87.4 | 13$^{b}$ |
| Little Club | 31.0$^{a}$ | 1.2$^{h}$ | 32.2 | 96.3 | 7$^{f}$ | 19.7$^{a}$ | 1.3$^{h}$ | 21.0 | 93.8 | 7$^{h}$ |

- Pus. = pustules.
- Eru. = Erupted pustules.
- Non-eru = Non-erupted pustules

*L.p. = Latent period (in days).

In a column, means followed by a common letter are not significantly at the 5% level by DMRT.

1-T*V Means (Race 11) L.S.D. (5%) = 0.118 L.S.D. (1%) = 0.156

2-T*V Means (Race 15) L.S.D. (5%) = 0.009 L.S.D. (1%) = 0.012

Regarding the colony size and pustule size expressed on 14 wheat varieties as affected by the infection with 2 physiologic races of *P. graminis tritici*. Data presented in Table (23) indicate no significance between varities as infected by race 11 in colony and pustule size with the exception of the highly susceptible variety "Little Club" which was significantly differentiated from the rest of tested varieties in both colony and pustule size and Sakha 202 which differed in colony area. The estimates between varieties except Little Club, ranged between (0.014 and 0.041 $mm^2$, and (0.011 and 0.035 $mm^2$) in both colony and pustule size, respectively.

The situation was completely different with race 15, the varieties showed significant differences regarding the size of each colony an pustule. The highest colony size was recorded with Little Club, however the reverse was recorded with Giza 168 and Sakha 202. On the other hand, the highest pustule size was recorded with "Little Club", however the reverse was recorded with Gemmeiza-7.

**Table (23).** Evaluation of 14 Egyptian wheat commercial varities at seedling stage against race 11 and 15 of stem rust in terms colony and pustule size under greenhouse conditions.

| No. | Wheat entries | Physiologic races | | | |
|---|---|---|---|---|---|
| | | Race 11 | | Race 15 | |
| | | Colony size | Pustule size | Colony size | Pustule size |
| 1 | Gemmeiza-1 | 0.031[b] | 0.018[b] | 0.019[f] | 0.012[e] |
| 2 | Gemmeiza-5 | 0.041[b] | 0.020[b] | 0.018[g] | 0.016[c] |
| 3 | Gemmeiza-7 | 0.033[b] | 0.016[b] | 0.028[b] | 0.004[i] |
| 4 | Gemmeiza-9 | 0.017[b] | 0.016[b] | 0.027[c] | 0.008[h] |
| 5 | Giza 160 | 0.038[b] | 0.035[b] | 0.020[e] | 0.020[b] |
| 6 | Giza 163 | 0.023[b] | 0.020[b] | 0.015[i] | 0.012[e] |
| 7 | Giza 164 | 0.014[b] | 0.011[b] | 0.018[g] | 0.010[g] |
| 8 | Giza 167 | 0.020[b] | 0.017[b] | 0.016[h] | 0.014[d] |
| 9 | Giza 168 | 0.018[b] | 0.015[b] | 0.012[k] | 0.010[g] |
| 10 | Sakha 8 | 0.022[b] | 0.020[b] | 0.020[e] | 0.016[c] |
| 11 | Sakha 61 | 0.023[b] | 0.021[b] | 0.022[d] | 0.016[c] |
| 12 | Sakha 93 | 0.015[b] | 0.013[b] | 0.014[j] | 0.012[e] |
| 13 | Sakha 202 | 0.014[b] | 0.012[b] | 0.012[k] | 0.011[f] |
| 14 | Little Club | 0.073[a] | 0.070[a] | 0.032[a] | 0.030[a] |

In a column, means followed by a common letter are not significantly at the 5% level by DMRT.

1-T*V Means (Race 11) L.S.D. (5%) = 0.0005 L.S.D. (1%) = 0.0007

2-T*V Means (Race 15) L.S.D. (5%) = 0.0260 L.S.D. (1%) = 0.0347

**B. Histological studies**

Regarding the relation between stem rust resistance and certain anatomical characters in certain wheat cultivars, at seedling stage data presented in Table (24) reveal that resistant cultivars exceeded the susceptible ones in the thickness of epidermis, outer wall, cuticle and sclerenchymatious tissues. On the other hand, the chollenchymatious tissues were not conspicuous in seedling sections. A significance could be detected between Sakha 93 and Sakha 92, and between Sids-1 and Sids-5 in the thickness of cuticle and outer wall and between Sakha 93, both of Sakha 92 and Sids-1 and Sids-5 in epidermis thickness and the area of sclerenchymatious tissues.

Regarding the situation of the anatomical characters of leaves at adult stage, data presented in Table (25) showed a reverse trend as compared to the case of seedlings regarding the cuticle and outer wall thickness, however the rest of characters run in parallel line with those of seedling. Both of Sids-1 and Sids-5 were significantly differentiated from both Sakha 93 and Sakha 92 in cuticle width. However Sakha 93 significantly increased in epidermis thickness and sclernchymatious area compared to the rest of tested cultivars.

Regarding the relation between stem rust resistance and the anatomical characters of stems in 4 wheat cultivars, data in Table (26) revealed that Sids-5 followed by both of Sids-1 and Sakha 93 were significantly increased in epidermis thickness comparing with Sakha 92.

**Table (24)** Thickness (in micron) of cuticle and outer wall (A), epidermis (B) and sclerenchyma tissues area (C) of leaf blade as a criteria for stem rust resistance in four Egyptian wheat varieties at seedling stage.

| Wheat varieties | A | B | C |
|---|---|---|---|
| Sakha 93 | 2.89[a] | 12.23[a] | 35.56[a] |
| Sakha 92 | 2.75[a] | 10.19[b] | 32.43[b] |
| Sids-1 | 1.72[b] | 10.03[b] | 32.17[b] |
| Sids-5 | 1.25[c] | 7.50[c] | 25.50[c] |
| M-mean | 2.16 | 9.98 | 31.41 |

- In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

| - Comparison | LSD (%) | LSD (1%) |
|---|---|---|
| 2-V*M mean | 0.376 | 0.511 |

**Table (25)** Thickness (in micron) of cuticle and outer wall (A), epidermis (B) and sclerenchyma tissues area (C) of leaf blade as a criteria for stem rust resistance in four Egyptian wheat varieties at adult stage.

| Wheat varieties | A | B | C |
|---|---|---|---|
| Sakha 93 | 2.50[b] | 12.50[a] | 40.50[a] |
| Sakha 92 | 2.50[b] | 10.03[b] | 40.03[b] |
| Sids-1 | 3.75[a] | 7.50[d] | 32.50[d] |
| Sids-5 | 3.75[a] | 8.75[c] | 35.50[c] |
| M-mean | 3.12 | 9.69 | 37.13 |

- In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

| - Comparison | LSD (%) | LSD (1%) |
|---|---|---|
| 2-V*M mean | 0.04 | 0.05 |

- **A** = Thickness of cuticle and outer wall.
- **B** = Thickness of epidermis.
- **C** = Sclerenchyma tissues area.

The situation was quite different in case of cuticle and outer wall, since Sids-1 was significantly differentiated from Sids-5, Sakha 93 and Sakha 92 in this regard within the transition section of stems at adult stage.

Concerning the relation between stem rust resistance at adult and the area of either chollenchyma or sclerenchyma area in 4 wheat cultivars, data presented in Table (27) indicated the presence of significance between Sids-5, Sids-1, and between Sakha 92 and Sakha 93 in chollenchymatious area. It was noticed that the susceptible cultivars exhibited higher areas than the resistant ones. The reverse was noticed with the sclerenchymatious area, since the resistant cultivars exceeded the susceptible ones. Sakha 93 significantly increased from Sakha 92, Sids-1 and Sids-5 in this regard. As for the (%) of collenchyma/sclerenchyma the presented data indicated that susceptible cultivars overcomed the resistant ones in this respect.

**Table (26)** Epidermis thickness, cuticle and outer layer of wheat stems as affected by stem rust infection in four cultivars at adult stage.

| Wheat varieties | Thickness (micron) | |
|---|---|---|
| | Cuticle and outer wall | Epidermis |
| **Sakha 93** | $2.50^{c}$ | $6.33^{b}$ |
| **Sakha 92** | $2.03^{d}$ | $6.03^{c}$ |
| **Sids-1** | $5.17^{a}$ | $6.44^{b}$ |
| **Sids-5** | $3.67^{b}$ | $7.50^{a}$ |
| **M-mean** | 3.34 | 6.58 |

- In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

| - Comparison | LSD (%) | LSD (1%) |
|---|---|---|
| 2-V*M mean | 0.19 | 0.27 |

**Table (27).** Collenchyma and sclerenchyma tissues expressed in ($mm^2$) as a criteria to stem rust resistance in the stems of 4 wheat cultivars at adult stage.

| Wheat varieties | Collenchyma | Sclerenchyma | % of Collenchyma to sclerenchyma |
|---|---|---|---|
| **Sakha 93** | $9.42^{d}$ | $40.50^{a}$ | 23.25 |
| **Sakha 92** | $10.50^{c}$ | $32.50^{b}$ | 32.30 |
| **Sids-1** | $12.50^{b}$ | $27.50^{d}$ | 45.45 |
| **Sids-5** | $14.50^{a}$ | $30.50^{c}$ | 47.54 |
| **M-mean** | 11.73 | 32.75 | |

- In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

| - Comparison | LSD (%) | LSD (1%) |
|---|---|---|
| 2-V*M mean | 0.08 | 0.11 |

**C. Effect of stem rust infection versus leaf cutting on root weight:**

Data presented in Table (28) indicated the behavior four wheat entries as affected by either rust infection or leaf cutting on fresh root weight at seedling stage. These data indicated that the highest reduction in root weight was recorded on Giza 160 (22.9%) followed by Giza 167 (6.5%). However, no effect was detectable on Sakha 61 (0.0%) due to infection or leaf cutting during the first interval.

By the time elapse, during the second interval, the situation was quite different, since the highest reduction was recorded with Giza 165 (21.5%) followed by Giza 160 (13.3%) and Giza 167 due to the cutting application (6.5%). The least reduction was noticed with Sakha 61 under the stress of cutting (1.5%).

Generally, the presented data revealed that reduction in root weight due to infection exceeded those due to cutting within all tested entries with the exception of Sakha 61. Similar trend was observed within most of the tested entries with the exception of Giza 165, Giza 167 and Sakha 61 in which the effect of cutting overcome that due to infection reaching it's maximum in Sakha 61, in which the effect of infection reached (0.0%) comparing with the control at the third interval.

**Table (28).** Effect of either stem rust infection or leaf cutting on root fresh weights (g.) in four vars. during 3 intervals at seedling stage.

| Vars. | Treatments | Dates* | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1st date | | 2nd date | | 3rd date | |
| | | Weight (g.) | Reduction (%) | Weight (g.) | Reduction (%) | Weight (g.) | Reduction (%) |
| Giza 160 | Infection | 0.1600 | 22.9 | 0.1300 | 13.3 | 0.1250 | 15.3 |
| | Cutting | 0.2000 | 3.6 | 0.1450 | 3.3 | 0.1400 | 5.1 |
| | Control | 0.2075 | - | 0.1500 | - | 0.1475 | - |
| Giza 165 | Infection | 0.1425 | 5.0 | 0.1275 | 21.5 | 0.1775 | 6.6 |
| | Cutting | 0.1475 | 1.6 | 0.1550 | 4.6 | 0.1575 | 17.1 |
| | Control | 0.1500 | - | 0.1625 | - | 0.1900 | - |
| Giza 167 | Infection | 0.1950 | 6.5 | 0.1875 | 1.3 | 0.2250 | 5.3 |
| | Cutting | 0.2025 | 2.9 | 0.1775 | 6.5 | 0.2150 | 9.5 |
| | Control | 0.2085 | - | 0.1900 | - | 0.2375 | - |
| Sakha 61 | Infection | 0.1825 | 0.0 | 0.1625 | 2.9 | 0.2225 | 0.0 |
| | Cutting | 0.1825 | 0.0 | 0.1650 | 1.5 | 0.1950 | 12.35 |
| | Control | 0.1825 | - | 0.1675 | - | 0.2225 | - |

*Starting at disease on set and continued at 6 days interval.

**III. Field experiments:**

**Evaluation of certain wheat entries to stem rust disease during 1998/99 and 1999/2000 growing seasons:**

Data presented in Table (29) revealed the evaluation of 21 wheat entries against stem rust in terms of (AUDPC). These data reveal development of rust reaction during 3 intervals (*i.e.* 8 days) the presented data indicated that the least value of AUDPC was recorded with the wheat cultivar Giza 168 (22.00) followed by Gemmeiza-5 (25.00). On the other hand, The highest value was recorded with Sohag-3 (242.64) followed by Sohag-1 (230.00), Sakha 8 (205.32) and Giza 160 (196.03). The rest tested entries showed intermediate response lied between the two limits. All of the tested entries showed susceptible response toward the disease, with the exception of Giza 168 which was moderate resistant. This was the situation during 1998/99, since the data in Table (30) revealed that out of the 21 tested entries, 17 showed susceptibility, 3 were moderate susceptible and one was moderate resistant.

On the other hand, the highest value of (AUDPC) was recorded with Sohag-3 (186.70) followed by Sakha 8 (168.70), Giza 160 (155.30) and Sohag-1 (145.00), however, the least value was recorded with Giza 157 (19.33), Sakha 61 (21.33), and both of (Sids-8, Giza 165, and Sakha 202 which recorded (25.33). The rest of tested entries showed intermediate response toward the disease during 1999/2000.

**Table (29).** Evaluation of 21 wheat entries against stem rust (*P. graminis tritici*) under field condition in terms of Area Under Disease Progressive Curve (AUDPC) during 1998/99.

| No. | Wheat entries | Disease Severity* | | | | AUDPC |
|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | |
| 1 | Sids-1 | 0 | 3 S | 13.33 S | 30 S | 136.33 |
| 2 | Sids-6 | 0 | 3 S | 4 S | 8.33 S | 40.32 |
| 3 | Sids-7 | 0 | 3 S | 10 S | 20 S | 93.00 |
| 4 | Sids-8 | 0 | 4 S | 8.33 S | 10 S | 52.33 |
| 5 | Sids-9 | 0 | 2 S | 4 S | 10 S | 46.00 |
| 6 | Giza 157 | 0 | 6.67 S | 13.33 S | 20 S | 100.00 |
| 7 | Giza 160 | 0.67 S | 10 S | 23.33 S | 40 S | 196.03 |
| 8 | Giza 164 | 0 | 3 S | 6.67 S | 10 S | 49.67 |
| 9 | Giza 165 | 0 | 2 S | 8.33 S | 10 S | 50.33 |
| 10 | Giza 167 | 0 | 2 S | 5 S | 10 S | 47.00 |
| 11 | Giza 168 | 0 | 0 | 2 MR | 5 MR | 22.00 |
| 12 | Sakha 8 | 1.33 S | 13.33 S | 26.67 S | 40 S | 205.32 |
| 13 | Sakha 61 | 0 | 6.67 S | 8.33 S | 20 S | 95.00 |
| 14 | Sakha 69 | 0 | 8.33 S | 16.67 S | 20 S | 105.00 |
| 15 | Sakha 202 | 0 | 4 S | 8.33 S | 10 S | 52.33 |
| 16 | Gemmeiza-3 | 0 | 2 S | 3 S | 5 S | 40.32 |
| 17 | Gemmeiza-5 | 0 | 1.33 S | 5 S | 10 S | 25.00 |
| 18 | Gemmeiza-7 | 0 | 2 S | 5 S | 10 S | 47.00 |
| 19 | Sohag-1 | 8.33 S | 20 S | 40 S | 43.33 S | 230.00 |
| 20 | Sohag-3 | 1.6 S | 16.67 S | 30 | 33.33 S | 242.64 |
| 21 | Beni Sweif-1 | 0 | 6.67 S | 20 S | 30 S | 196.70 |

*Each figure was calculated as the mean of 3 replicates.

**Table (30).** Evaluation of 21 wheat entries against stem rust (*P. graminis tritici*) under field condition in terms of Area Under Disease Progressive Curve (AUDPC) during 1999/2000.

| No. | Wheat entries | Disease Severity* | | | | AUDPC |
|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | |
| 1 | Sids-1 | 0 | 6.67 MS | 10 MS | 20 MS | 77.33 |
| 2 | Sids-6 | 0 | 1.33 S | 4 S | 6.67 S | 32.01 |
| 3 | Sids-7 | 0 | 5 S | 10 S | 16.67 S | 81.68 |
| 4 | Sids-8 | 0 | 1.33 S | 4 S | 5 S | 25.33 |
| 5 | Sids-9 | 0 | 2 MS | 5 MS | 8.33 MS | 40.32 |
| 6 | Giza 157 | 0 | 1.33 S | 2 S | 4 S | 19.33 |
| 7 | Giza 160 | 1.33 S | 10 S | 20 S | 30 S | 155.30 |
| 8 | Giza 164 | 0 | 1.33 S | 3 S | 8.33 S | 37.65 |
| 9 | Giza 165 | 0 | 1.33 S | 4 S | 5 S | 25.33 |
| 10 | Giza 167 | 0 | 3 MS | 5 MS | 10 MS | 48.00 |
| 11 | Giza 168 | 0 | 3 MR | 5 MR | 10 MR | 48.00 |
| 12 | Sakha 8 | 1.33 S | 16.67 S | 26.67 S | 30 S | 168.70 |
| 13 | Sakha 61 | 0 | 1.33 S | 4 S | 4 S | 21.33 |
| 14 | Sakha 69 | 0 | 4 S | 8.33 S | 8.33 S | 45.65 |
| 15 | Sakha 202 | 0 | 1.33 S | 4 S | 5 S | 25.33 |
| 16 | Gemmeiza-3 | 0 | 4 S | 8.33 S | 10 S | 52.33 |
| 17 | Gemmeiza-5 | 0 | 1.33 S | 5 S | 10 S | 46.33 |
| 18 | Gemmeiza-7 | 0 | 1.33 S | 5 S | 10 S | 46.33 |
| 19 | Sohag-1 | 0 | 8.33 S | 16.67 S | 30 S | 145.00 |
| 20 | Sohag-3 | 1.6 S | 16.67 S | 30 | 33.33 S | 186.70 |
| 21 | Beni Sweif-1 | 0 | 5 S | 10 S | 16.67 S | 81.68 |

*Each figure was calculated as the mean of 3 replicates.

Data presented in Table (31) revealed the evaluation of 21 wheat entries against stem rust (*P. graminis tritici*) in terms of disease severity, and each of 1000 k.w. and 10 spike weight from either protected (P) or infected (I) plot. These data indicated that the highest rust reaction was recorded with Sohag-3 (43.3S) followed by (Sakha 8 and Giza 160 (40S) and Sohag-1 (36.0S). The least response was recorded with Giza 168 (5MR) and Gemmeiza-5 (5S). The rest of entries showed intermediate susceptible responses:

As regard to the 1000 k.w. within the completely protected plots (P), the presented data showed slight significance between the tested entries. The wheat cultivar Gemm.-3 was significantly differentiated from the other entries followed by both of Sakha 61 and Beni-Sweif-1.

Regarding the infected plots, the presented data indicated presence of significant increase in 1000 k.w. of Gemmeiza-3 followed by Sohag-1, while the lowest 1000 k.w. was for Giza 165. The rest entries had 1000 k.w. between them.

The presented data also revealed highly significant difference between infected and protected plots, with the exception of the plots of Sids-9, Giza 164, Sakha 202, Gemmeiza-5 and Sohag-1, since the difference was nearly significant. On the other hand, a non-significant difference between no infected and infected plots in cases of Sakha 69 and Gemmeiza-3 was observed. The presented data also revealed that the highest reduction (%) in 1000 k.w. was observed in the wheat cultivar Giza 160 (20.01) followed by Sids-1 (16.14), however the least value of reduction was recorded with Gemmeiza-3 (4.42) and Sakha 69 (4.80).

Concerning the 10 spike weight from the perspective of the above mentioned parameters, the presented data of the same table indicated that Sids-6 was significantly differentiated from the tested entries within the protected plots followed by (Sids-1, Sakha 69 and Gemmeiza-3), (Sakha 202 and Giza 160) and both of (Sids-8, Giza 157, Sakha 61 and Beni Sweif-1). The situation was quite different in case of infected plots, since Sids-6 and Sids-7 occupied the highest rank in this regard and significantly differentiated from the rest of entries, followed by Gemmeiza-3, (Sids–7 and Sakha 202), (Sids-9 and Beni Sweif-1) and each of (Sids-8, Sids 9, Sakha 61 and Sohag-1) and (Sids-8, Sakha 61, Gemmeiza-5 and Sohag-1), (Giza 157, Giza 160, Sakha 8, Gemmeiza-7 and Sohag-3) and (Sids-1, Giza 164, Giza 165, Giza 168).

Looking to the difference between both infected and protected plots, the presented data indicated that this difference was highly significant between the vast majority of entries with exception of Sohag-1 in which it was significant while Gemmeiza-5 and Sohag-3 that showed insignificance.

As regard to the reduction percent in 10 spike weight as affected by the treatments, the presented data indicated that the highest affected entries were Sakha 69 (24.00) followed by Sids-1 (23.68) and Giza 157 (20.88) whereas the least weight was recorded wit Gemmeiza-5 (3.11) followed by Sohag-3 (4.27).

The previous comment dealt with the trend of evaluation during 1998/99.

Concerning the evaluation during 1999/2000 data presented in Table (32) revealed that similar trend was observed within

entries regarding the stem rust severities since the highest disease rate was recorded with Sohag-3 (33.33 S) followed by Sakha 8 , Giza 160 and Sohag-1 (30 S). On the other hand, the least rates of disease severity was recorded with Giza 168 (10 MR) followed by Giza 167, Sids-1 and Sids-9 which recorded 10 MS, 20 MS, and 8.33 MS respectively. The rest of tested entries showed the same trend as in the previous season with slight decrease in disease severity.

The presented data also revealed that Gemmeiza-3 occupied the highest 1000 k.w. in either protected or infected plots, however Giza 157 and Giza 165 exhibited the lowest weight. This trend seemed to be similar to that of the last season, but the weight value were relatively less, with similar significant levels. Regarding the 1000 k.w. within infected plots the results seemed to be parallel to that of 1998/99 and still Gemmeiza-3 occupied the highest weight and Giza 157 exhibited the least one. Regarding the difference between protected and infected plots, the presented data indicated that the difference was highly significant between the treatments within all of the tested entries.

The presented data, also revealed that the more affected entry by the disease was Giza 160 followed by Sakha 8, since the reduction (%) was 27.03 and 23.82, in this respect. However the less affected ones were Giza 164, Giza 157 and Sakha 202 since the reduction (%) was 8.44, 9.02 and 9.70, respectively.

Concerning the 10 spike weight as affected by the complete protection treatment, data in Table (32) indicated that Gemmeiza-3 (26.69) was significantly differentiated from the rest of entries

followed by Sakha 202 (25.52). Giza 165 exhibited the least weight and was significantly different from the rest of entries with the exception of Giza 160.

The same trend was observed in case of serve infection, since Gemmeiza-3 and Sakha 202 exhibited the highest weight followed by Gemmeiza-9, Gemmeiza-7 and Sohag-1. However, the least weight was observed with Giza 165, Giza 160 and Sakha 8. These data seemed to be quite similar to those of 1998/99 with few exceptions. Likewise, the data indicated that the difference between treatments showed high significance within either of the tested entries.

As regard to the reduction (%) in 10 spike weight, as affected by the treatments, the data indicated that the highest reduction (%) was recorded with Sakha 69 (30.14) followed by Sids-1 (28.97) and Sakha 8 (23.28). However, the least values were exhibited by Gemmeiza-7 (7.62), Sohag-1 (8.84) and Giza 167 (9.37). The rest of tested entries exhibited values lied in between.

**Table (31).** The response of 21 wheat varieties and entries against stem rust infection under field condition expressed in terms of 1000 k.w, 10 spike weight and their loss % in either infected (I) or protected plots (P), at Sakha during 1998/1999.

| Varieties | Disease severity* | 1000 Kernel weight (g) | | | | 10 spike weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | P | I | Diff. | Reduction % | P | I | Diff. | Reduction % |
| **Sids 1** | 30.00 S | $50.56^{ij}$ | $42.40^{j}$ | $8.16^{**}$ | 16.14 | $27.03^{fgh}$ | $20.63^{i}$ | $6.40^{**}$ | 23.68 |
| **Sids 6** | 8.33 S | $62.77^{bc}$ | $57.36^{bc}$ | $5.41^{**}$ | 8.61 | $36.40^{a}$ | $32.24^{a}$ | $4.16^{**}$ | 11.41 |
| **Sids 7** | 20.00 S | $58.75^{de}$ | $53.34^{def}$ | $5.40^{**}$ | 9.20 | $32.81^{b}$ | $28.85^{a}$ | $3.96^{**}$ | 12.03 |
| **Sids 8** | 10.00 S | $56.16^{efg}$ | $49.50^{gh}$ | $6.66^{**}$ | 11.80 | $29.73^{d}$ | $25.93^{efg}$ | $3.79^{**}$ | 12.67 |
| **Sids 9** | 10.00 S | $57.92^{def}$ | $53.96^{cde}$ | $3.96^{*}$ | 6.82 | $28.02^{ef}$ | $26.65^{de}$ | $1.37^{**}$ | 4.90 |
| **Giza 157** | 20.00 S | 53.36g-j | $46.88^{hi}$ | $6.48^{**}$ | 12.14 | $30.60^{cd}$ | $24.21^{h}$ | $7.34^{**}$ | 20.88 |
| **Giza 160** | 40.00 S | $54.70^{fgh}$ | $43.77^{ij}$ | $10.94^{**}$ | 20.01 | $25.69^{i}$ | $23.06^{h}$ | $2.63^{**}$ | 10.18 |
| **Giza 164** | 10.00 S | $51.85^{hij}$ | $48.35^{h}$ | $3.50^{*}$ | 6.75 | $26.77^{gi}$ | $21.35^{i}$ | $5.42^{**}$ | 20.25 |
| **Giza 165** | 10.00 S | $42.76^{k}$ | $37.36^{k}$ | $5.40^{**}$ | 12.62 | $22.74^{k}$ | $21.69^{i}$ | $1.05^{**}$ | 4.62 |
| **Giza 167** | 10.00 S | $50.17^{j}$ | $44.04^{ij}$ | $6.13^{**}$ | 12.18 | $28.22^{e}$ | $25.23^{g}$ | 2.99** | 10.57 |
| **Giza 168** | 5.00 MR | $50.44^{j}$ | $43.95^{ij}$ | $6.49^{**}$ | 12.86 | $26.41^{hi}$ | $21.54^{i}$ | $4.87^{**}$ | 18.41 |
| **Sakha 8** | 40.00 S | $52.98^{g-j}$ | $44.58^{ij}$ | 8.40** | 15.84 | $26.91^{fgh}$ | $23.08^{h}$ | $3.83^{**}$ | 14.19 |
| **Sakha 61** | 20.00 S | 65.09b | $55.28^{cde}$ | $9.81^{**}$ | 5.37 | $29.55^{d}$ | $26.04^{efg}$ | $3.51^{**}$ | 11.80 |
| **Sakha 69** | 20.00 S | $54.78^{fgh}$ | $52.15^{efg}$ | $2.63^{ns}$ | 4.80 | $32.82^{b}$ | $24.94^{g}$ | 7.88** | 24.00 |
| **Sakha 202** | 10.00 S | $60.29^{cd}$ | $56.39^{bcd}$ | $3.91^{*}$ | 6.47 | $31.54^{c}$ | $28.71^{c}$ | $2.83^{**}$ | 8.96 |
| **Gemmeiza 3** | 8.33 S | $69.05^{a}$ | $65.99^{a}$ | $3.07^{ns}$ | 4.42 | $33.89^{b}$ | $31.13^{b}$ | $2.76^{**}$ | 8.14 |
| **Gemmiza 5** | 5.00 S | $54.23^{f-i}$ | $50.13^{fgh}$ | $4.09^{*}$ | 7.54 | $26.22^{hi}$ | $25.40^{fg}$ | $0.82^{ns}$ | 3.11 |
| **Gemmeiza 7** | 10.00 S | $55.77^{efg}$ | $48.57^{gh}$ | $7.20^{**}$ | 12.91 | $26.50^{hi}$ | $23.35^{h}$ | $3.15^{**}$ | 11.89 |
| **Sohag 1** | 36.67 S | $63.10^{bc}$ | $59.41^{b}$ | $3.69^{*}$ | 5.85 | $27.68^{efg}$ | $26.44^{ef}$ | $1.24^{*}$ | 4.46 |
| **Sohag 3** | 43.33 S | $58.79^{de}$ | $54.41^{cde}$ | $4.37^{**}$ | 7.42 | $23.85^{j}$ | $22.83^{h}$ | $1.02^{ns}$ | 4.27 |
| **Bani Sweif-1** | 30.00 S | $63.13^{bc}$ | $56.72^{bcd}$ | $6.41^{**}$ | 10.16 | $29.77^{d}$ | $27.53^{d}$ | $2.24^{**}$ | 7.50 |

*Each figure was calculated as the mean of 3 replicates.

**Table (32).** The response of 21 wheat varieties and entries against stem rust infection under field condition expressed in terms of 1000 k.w, 10 spike weight and their loss % in either infected (I) or protected plots (P), at Sakha during 1999/2000.

| Varieties | Disease severity* | 1000 Kernel weight (g) | | | | 10 spike weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | P | I | Diff. | Reduction % | P | I | Diff. | Reduction % |
| **Sids 1** | 20.00 MS | $41.07^{f}$ | $32.06^{h}$ | $9.01^{**}$ | 21.94 | $21.95^{d}$ | $15.59^{ij}$ | 6.36** | 28.97 |
| **Sids 6** | 6.67 S | $37.07^{jk}$ | $32.41^{gh}$ | $4.66^{**}$ | 11.67 | $21.69^{de}$ | $18.40^{ef}$ | 3.29** | 15.18 |
| **Sids 7** | 16.67 S | $38.71^{hi}$ | $35.01^{e}$ | $3.70^{**}$ | 9.57 | $21.54^{de}$ | 18.71d$^{ef}$ | 2.83** | 13.15 |
| **Sids 8** | 5.00 S | $37.79^{ij}$ | $32.26^{h}$ | $5.53^{**}$ | 14.62 | $20.00^{fg}$ | $16.90^{gh}$ | 3.11** | 15.53 |
| **Sids 9** | 8.33 MS | $40.09^{fg}$ | $33.60^{fg}$ | $6.49^{**}$ | 16.16 | $19.38^{gh}$ | $16.21^{hi}$ | 3.17** | 16.37 |
| **Giza 157** | 4.00 S | 31.27m | 28.44I | $2.83^{**}$ | 9.02 | $17.70^{i}$ | $14.52^{k}$ | 3.18** | 17.97 |
| **Giza 160** | 30.00 S | $32.98^{l}$ | $24.06^{j}$ | $8.92^{**}$ | 17.03 | $15.49^{j}$ | $13.17^{l}$ | 2.32** | 15.00 |
| **Giza 164** | 8.33 S | $37.32^{jk}$ | $34.17^{ef}$ | $3.16^{**}$ | 8.44 | $19.26^{gh}$ | $15.15^{jk}$ | 4.11** | 21.36 |
| **Giza 165** | 5.00 S | $33.82^{l}$ | $28.29^{i}$ | $5.50^{**}$ | 14.08 | $14.61^{j}$ | $11.88^{m}$ | 2.73** | 18.71 |
| **Giza 167** | 10.00 MS | $38.82^{hi}$ | $33.35^{fgh}$ | $5.47^{**}$ | 11.09 | $21.60^{de}$ | $19.58^{cd}$ | 2.02** | 9.37 |
| **Giza 168** | 10.00 MR | $39.69^{gh}$ | $35.29^{e}$ | $4.40^{**}$ | 16.27 | $20.25^{fg}$ | $17.31^{g}$ | 2.94** | 14.53 |
| **Sakha 8** | 30.00 S | $39.40^{k}$ | $27.72^{i}$ | $8.68^{**}$ | 23.82 | $18.70^{h}$ | $14.35^{k}$ | 4.35** | 23.28 |
| **Sakha 61** | 4.00 S | $44.64^{e}$ | $39.22^{d}$ | $5.42^{**}$ | 12.15 | $22.19^{d}$ | $18.47^{ef}$ | 3.72** | 16.76 |
| **Sakha 69** | 8.33 S | $36.64^{jk}$ | $32.09^{h}$ | $4.55^{**}$ | 12.40 | $21.96^{d}$ | $15.34^{ijk}$ | 6.62** | 30.14 |
| **Sakha 202** | 5.00 S | $48.81^{d}$ | $44.05^{bc}$ | $4.76^{**}$ | 9.70 | $25.52^{b}$ | $22.37^{a}$ | 3.15** | 12.34 |
| **Gemmeiza 3** | 10.00 S | $53.37^{a}$ | $46.95^{a}$ | $6.42^{**}$ | 11.91 | $26.69^{a}$ | $22.15^{a}$ | 4.54** | 17.02 |
| **Gemmiza 5** | 10.00 S | 50.58b$^{bc}$ | $39.66^{d}$ | $10.92^{**}$ | 21.58 | $23.95^{c}$ | $20.61^{b}$ | 3.34** | 13.70 |
| **Gemmeiza 7** | 10.00 S | $47.84^{d}$ | $42.86^{c}$ | $4.98^{**}$ | 10.42 | $22.30^{d}$ | $20.60^{b}$ | 1.70** | 7.62 |
| **Sohag 1** | 30.00 S | $50.20^{c}$ | $45.02^{b}$ | $5.18^{**}$ | 10.31 | $21.73^{de}$ | $19.93^{bc}$ | 1.80** | 8.84 |
| **Sohag 3** | 33.33 S | $51.84^{b}$ | $43.14^{c}$ | $8.71^{**}$ | 16.79 | $20.75^{ef}$ | $17.87^{fg}$ | 2.88** | 13.88 |
| **Bani Sweif-1** | 16.67 S | 50.65b$^{bc}$ | $39.63^{d}$ | $11.02^{**}$ | 21.76 | $23.37^{c}$ | $19.39^{cde}$ | 3.98** | 17.03 |

*Each figure was calculated as the mean of 3 replicates.

**IV. Genetic studies for slow rusting under field condition:**

The genetical studies included the evaluation of 6 parents and their $F_1$ and $F_2$ as infected with mixture of stem rust (*P. graminis tritici*) physiologic races in a half dialell crosses resulted in 15, only 10 were selected and appointed, Table (33). The presented data indicated that most of the tested parents were moderate susceptible to susceptible *i.e.* Giza 167 (10MS to 8S), Sakha 8 (10S – 20S), Sakha 69 (10S – 20S), Sakha 61 (10S – 20S) and Sids-8 (10S – 10S). On the other hand, Gemmeiza-3 rated 10R-20R.

Regarding the $F_1$ plants, the presented data indicated that $F_1$ of the first cross Giza 167 × Sakha 8 was moderate susceptible, Giza 167 × Sakha 69 was susceptible (10S – 20S), however, Giza 167 × Sakha 61 and Giza 167 × Gemmeiza-3 rated (10R–20R), Giza 167 × Sids-8 was (20S – 30S), Sakha 8 × Sakha 69 was (20MS – 20S), Sakha 8 × Sakha 61 was (10S – 20S), Sakha 8 × Gemmeiza-3 was (10R–10MR), Sakha 8 × Sids-8 was (20MS–20S) and Sakha 69 × Gemmeiza-3 was (10R– 20R).

It could be concluded from these data that the direction of dominance tend to the parent having lower infection type in the 1$^{st}$, 3$^{rd}$, 4$^{th}$, 8$^{th}$, and 10$^{th}$ crosses and to the side of susceptibility in the rest of crosses.

Concerning the $F_2$ plants, the presented data indicated the presence of varied segregations of infection types over that noticed in the parents.

As regard to the number of genes governing the resistance among the tested crosses, data presented in Table (34) indicated that

As regard to the number of genes governing the resistance among the tested crosses, data presented in Table (34) indicated that two gene pairs seemed to be controlling stem rust resistance among the crosses with the exception of the crosses (Giza 167 × Sakha 69) and (Sakha 8 × Gemmeiza-3), which indicated that resistance was controlled by only one gene pair, recessive in the first cross and dominant in the second.

**Table (33).** Stem rust disease severity frequency distribution for parents, $F_1$ and $F_2$ populations of eleven wheat crosses against naturally infected with *Puccinia graminis* f. sp. *tritici* at the adult stage, under field conditions during 2000/2001.

| Cross No. | Cross name | | No. of tested plants | Rust severity classes | | | | | | | | | | X* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 10R | 20R | 10 MR | 20 MR | 10 MS | 20 MS | 10S | 20S | 30S | 40 S | |
| 1 | **Giza 167 × Sakha 8** | $P_1$ | 30 | | | | | 7 | 15 | 8 | | | | 12.53 |
| | | $P_2$ | 30 | | | | | | | 19 | 11 | | | 13.67 |
| | | $F_1$ | 30 | | | | | 30 | | | | | | 8.00 |
| | | $F_2$ | 180 | 30 | 40 | 18 | 22 | 23 | 10 | 27 | 10 | | | 7.12 |
| 2 | **Giza 167 × Sakha 69** | $P_1$ | 30 | | | | | 5 | 13 | 12 | | | | 12.27 |
| | | $P_2$ | 30 | | | | | | | 23 | 7 | | | 12.33 |
| | | $F_1$ | 30 | | | | | | | 16 | 14 | | | 13.20 |
| | | $F_2$ | 180 | 8 | 22 | 10 | 10 | 67 | 31 | 28 | 4 | | | 8.97 |
| 3 | **Giza 167 × Sakha 61** | $P_1$ | 30 | | | | | 5 | 13 | 12 | | | | 12.27 |
| | | $P_2$ | 30 | | | | | | | 24 | 6 | | | 12.00 |
| | | $F_1$ | 30 | 19 | 11 | | | | | | | | | 2.73 |
| | | $F_2$ | 180 | 53 | 49 | 25 | 21 | 7 | 6 | 12 | 7 | | | 5.46 |
| 4 | **Giza 167 × Gemmeiza-3** | $P_1$ | 30 | | | | | 10 | 14 | 6 | | | | 12.13 |
| | | $P_2$ | 30 | 22 | 8 | | | | | | | | | 2.53 |
| | | $F_1$ | 30 | 23 | 7 | | | | | | | | | 2.46 |
| | | $F_2$ | 180 | 60 | 33 | 29 | 25 | 13 | 17 | 3 | | | | 5.41 |
| 5 | **Giza 167 × Sids-8** | $P_1$ | 30 | | | | | | 5 | 13 | 12 | | | 12.27 |
| | | $P_2$ | 30 | | | | | | | 26 | 4 | | | 15.20 |
| | | $F_1$ | 30 | | | | | | | | 22 | 8 | | 12.67 |
| | | $F_2$ | 180 | | | | 30 | 15 | 33 | 40 | 37 | 21 | 4 | 15.66 |

X* = Population mean.

Table (33). Cont.

| Cross No. | Cross name | | No. of tested plants | Rust severity classes | | | | | | | | | | X* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 10R | 20R | 10 MR | 20 MR | 10 MS | 20 MS | 10S | 20S | 30S | 40 S | |
| 6 | Sakha 8 × Sakha 69 | $P_1$ | 30 | | | | | | | 20 | 10 | | | 13.3 |
| | | $P_2$ | 30 | | | | | | | 23 | 7 | | | 12.3 |
| | | $F_1$ | 30 | | | | | | 3 | 22 | 5 | | | 12.2 |
| | | $F_2$ | 180 | 40 | 23 | 10 | 37 | 10 | 20 | 34 | 6 | | | 7.6 |
| 7 | Sakha 8 × Sakha 61 | $P_1$ | 30 | | | | | | | 20 | 10 | | | 13.3 |
| | | $P_2$ | 30 | | | | | | | 24 | 6 | | | 12.0 |
| | | $F_1$ | 30 | | | | | | | 13 | 17 | | | 15.6 |
| | | $F_2$ | 180 | | | 15 | 13 | 53 | 40 | 42 | 12 | 5 | | 6.01 |
| 8 | Sakha 8 × Gemmeiza-3 | $P_1$ | 30 | | | | | | | 20 | 10 | | | 13.3 |
| | | $P_2$ | 30 | 22 | 6 | 2 | | | | | | | | 2.53 |
| | | $F_1$ | 30 | 11 | 9 | 10 | | | | | | | | 3.26 |
| | | $F_2$ | 180 | 46 | 60 | 26 | 9 | 26 | 8 | 3 | 2 | | | 5.08 |
| 9 | Sakha 8 × Sids-8 | $P_1$ | 30 | | | | | | | 20 | 10 | | | 13.3 |
| | | $P_2$ | 30 | | | | | | 27 | 3 | | | | 15.4 |
| | | $F_1$ | 30 | | | | | | 9 | 14 | 7 | | | 14.1 |
| | | $F_2$ | 180 | 30 | 46 | 49 | 27 | - | 8 | 10 | 10 | | | 6.02 |
| 10 | Sakha 69 × Gemmeiza-3 | $P_1$ | 30 | | | | | | | 23 | 7 | | | 12.3 |
| | | $P_2$ | 30 | 19 | 11 | | | | | | | | | 2.73 |
| | | $F_1$ | 30 | 24 | 6 | | | | | | | | | 2.40 |
| | | $F_2$ | 180 | 57 | 45 | 28 | 33 | 2 | 11 | 4 | | | | 5.01 |

**Table (34).** Stem rust severity phenotypic classes of ten wheat crosses inoculated with *Puccinia graminis* f. sp. *tritici* at the adult stage under field conditions during 2000/2001.

| Cross No. | Cross name | Phenotype | | Expected ratio | Chi-Squared value ($\chi^2$) |
|---|---|---|---|---|---|
| | | R | S | | |
| 1 | **Giza 167 × Sakha 8** | 110 | 70 | 9 : 7 | 1.728 |
| 2 | **Giza 167 × Sakha 69** | 50 | 130 | 1 : 3 | 0.740 |
| 3 | **Giza 167 × Sakha 61** | 148 | 32 | 13 : 3 | 0.111 |
| 4 | **Giza 167 × Gemmeiza-3** | 147 | 33 | 13 : 3 | 0.020 |
| 5 | **Giza 167 × Sids-8** | 30 | 150 | 3 : 13 | 0.512 |
| 6 | **Sakha 8 × Sakha 69** | 110 | 70 | 9 : 7 | 1.728 |
| 7 | **Sakha 8 × Sakha 61** | 28 | 152 | 3 : 13 | 1.205 |
| 8 | **Sakha 8 × Gemmeiza-3** | 141 | 39 | 3 : 1 | 1.066 |
| 9 | **Sakha 8 × Sids-8** | 152 | 28 | 13 : 3 | 1.205 |
| 10 | **Sakha 69 × Gemmeiza-3** | 163 | 17 | 15 : 1 | 3.134 |

## Discussion

Wheat (*Triticum aestivum* L.) is considered to be the essential food crop in the vast majority of the world countries. Wheat rusts in general and stem rust in particular are one of the limiting factors of mass production.

The presented study threw high lights on stem rust disease of wheat and it's control from the perspective of race dynamics, varietal resistance, and varietal evaluation taking into consideration certain physiological and genetical aspects dealing with slow rusting as an effective mechanism for disease resistance.

The obtained results gave evidence to the occurrence of wheat stem rust in the Northern governorates of Egypt according to the performed survey, estimated by 10-40% in the area grown to wheat.

The visual examination of the collected samples indicated accordant symptoms to those of wheat stem rust. On the other hand, the microscopical examination confirmed the identity of the casual agent of the disease as *Puccinia graminis* Pers. f. sp. *tritici* Eriks. & Henn. This results were supported by **Wiese (1977).**

The obtained results indicated presence of 6 and 5 physiologic races of *P. graminis tritici* during 1998/1999 and 1999/2000 growing seasons. Most of these races were recorded before. Race 11 is considered the predominate one. Similar results were reported in this regard by **Abd El-Hak *et al.* (1973, 1975 and 1982); Abu El-Naga *et al.* (1990 and 1993); El-Daoudi *et al.* (1992); El-Sherif et al. (1996) and Mohamed (2001).** In countries other than Egypt, similar results were reported by **Roelfs (1971) and Roelfs *et al.* (1993); Bartos *et al.* (1982); Lekomtseva *et al.* (1994); Manninger (1994); McVey *et al.***

**(1996 and 1997) and Harder (1999).** Likewise, the virulence formula *i.e.* *Sr*'s: 26, $Gt^{+}$, 9e, 36 and 11, 21 were the more frequent ones during 1998/1999 and 1999/2000, respectively. Consequently the more effective genes were *Sr* 26, *Sr* 9e and *Sr* $T_{t-1}$ and *Sr* 11 during the two seasons, respectively. Similar results were reported by **Abu El-Naga *et al.* (1990 and 1993); El-Daoudi *et al.* (1992) and Mohamed (2001)** who confirmed the effectiveness of *Sr* 26 and *Sr* 9e against stem rust uredospre populations.

Regarding the application of the recent nomenclature system adopted by **Roelfs and Martens (1988),** the obtained results gave evidence to the dominance of isolates TTT and RTK and RKT, RFT, MKT, and MFT during the two seasons. Similar results were reported by **Roelfs and McVey (1972); Martens and Dunsmore (1988); Roelfs and Martens (1988); Martens *et al.* (1989); and McVey *et al.* (1999).** It could be concluded from these results that *Sr*'s: 26, 9e, and to some extent *Sr* 8a are considered more effective genes against stem rust uredospore population during 1998/1999. However *Sr*'s: $T_{t-1}$ 9e, 11, 9e and 21 are effective during 1999/2000. If these results were compared with those of virulence formulae, a little be similarities would be observed with resistance genes, particularly *Sr*'s: 9e, 11, 6 and 21. This comprehensive conclusion indicated the common trend of such results. Similar results were recorded by **Abd El-Hak *et al.* (1982)** who confirmed that *Sr*'s: 22, 24 and 26 were resistant to most of stem rust isolates, however, *Sr* 's: 9e, 13, 27, 30 and Gt+ were resistant to most isolates. **Abu El-Naga *et al.* (1990 and 1993); El-Daoudi *et al.* (1992–1996) and El-Sherif *et al.* (1996),** stated the efficacy of *Sr*'s: 9e, 8a and 26 against stem rust during that periods. In countries other than Egypt, similar results were reported by **Casuli and Ruci (1991); Roelfs *et al.***

(1989, 1993 and 1995); **Harder *et al.* (1994) and McVey *et al.* (1996).** Their findings were in accordance with ours. On the other hand, **Bahadur *et al.* (1985)** recorded virulence to *Sr* 9e; **Roux (1989); Hu & Roelfs (1990); Harded & Dunsmore (1990); Singh *et al.* (1992) and Kebede *et al.* (1995)** indicated the presence of virulence to *Sr* 8a. The results could be understood on the basis of the change in the prevalent environment and to the genetic make up of the host plant.

In relation to the matching test performed between *Sr*'s and commercials virsus 30 isolates of *P. graminis tritici* at seedling stage, the obtained results indicated that the commercial varities varied in their inclusion of postulated resistant genes. For example, Sakha 61 include 3 genes (the least), however, Gemmeiza-7 included 13 genes (the highest). On the other hand, the results gave evidence to the presence of *Sr*'s: 36, 30, 29 followed by 7b and 8a, as the more frequent and commonest genes. However, *Sr*'s: $T_{t-1}$, 26, 21, 9e appeared in lower frequencies within the commercials.

If we put these results in comparison with the abovementioned ones, we would find that the common genes within cultivars are lacked as effective ones. However, those effective are less frequent or less common herein. This explanation seemed to be comprehensive and logical, because the basis of the first test i.e. virulence formulae depend upon the spore samples which were collected from the susceptible cultivars. However, the basis of the matching test "gene postulation" depend upon the matching of *Sr*'s (known gene varieties) and the commercials (unknown gene cultivars) virsus high number of isolates.

This results seemed to be logical since the local commercials require *Sr*'s: Tt-1, 26, 21 and 9e which are in turn effective in the virulence analysis results which were reported by **Claude *et al.* (1986);**

**Hu and Roelfs (1986); Singh and McIntosh (1986); Hu (1988) and Imbaby (1997).**

As regard to the evaluation of the test cultivars on the basis of partial resistance against stem rust, the obtained results revealed that varieties such as Little Club, Giza 160 and Sakha 8 proved to be fast rusters. They were characterized by higher values of both pustules and colony sizes, shorter incubation periods and higher rates of erupted pustules comparing with those recorded with the slow rusting varieties i.e. Gemmeiza-1, Gemmeiza-9, Giza 164 and Sakha 93 which exhibited reverse values in this regard. These results were supported by those of **Vander Plank (1963), Hooker (1967), Ohm and Shaner (1976), El-Daoudi *et al.* (1985), Kapoor and Joshi (1981 and 1986) and Ragab *et al.* (1989)** who confirmed that cultivars proved to have slow rusting or horizontal resistance exhibited lower pustule density, small pustule and/or colony size, prolonged latent period and reduced spore production.

As for the anatomical examination of both slow or fast rusting varieties as a trait combined with partial resistance, the obtained results indicated that slow reusters were characterized by an increase in cuticle, epidermis and outer layers associated with transition section of leaves or stems in seedling or adult plants when compare with those of fast rusters these results seemed to be in accordance with the findings of **Parsada (1964), Naguib (1973), Ragab *et al.* (1979), Palmer and Wilcoxson (1982), Imbaby (1995) and Aly (1999)** who indicated that the presence of leaf hairs, lower number of stomata on leaf surface, thickness of epidermal cells are considered factors with partial resistance against rust.

As regard to the effect of either stem rust infection or leaf cutting on fresh weight of roots at seedlings of four entries. The obtained results gave evidence to the exceeding of infection over cutting in inducing in root weights reduction in most cases with few exceptions at the third interval. On the other hand, it could be concluded that the pronounce effect on root reduction could be recognized with the highly susceptible entries such as Giza 160 and Giza 165. However, this effect was reversed in case of entries having low level of infection such as Giza 167 and Sakha 61. These results could be explained on the basis of high susceptibility with stem rust, since nutrient and water supply translocated from the roots to the leaves through the xylem bundles. However, the digested food translocated from leaves through the phloem elements in the stem. The problem herein, is that, rust infection is restricted in the area of cortex and phloem in both leaves and stems. This would block or at least minimize the digested nutrient translocated to the roots. This my be the reason behind the decrease in root weight.

Regarding the evaluation of certain local wheat cultivars from the perspective of disease and yield parameters, the obtained results indicated that Giza 168 and Giza 157 exhibited the lowest AUDPC in the first and in the second season, respectively. However, the reverse was recorded with Sohag-3 in both seasons. The highest weight of 1000 k.w. was observed in Gemmeiza-3, while, the lowest 1000 k.w. was noticed with Giza 165 during 1998/1999. On the other hand, the least reduction in 1000 k.w. was recorded with Gemmeiza-3, however Giza 160 exhibited the highest reduction in this eight. These results would give us the ground to say that slow rusting varieties or those exhibited partial resistance are closely related with the less AUDPC and high 1000 k.w. and 10 spike weight. Similar results were reported by **Rowel**

**(1982), Khalifa (1986), Bassiouni *et al.* (1987), El-Daoudi *et al.* (1990), McGrath & Pennypaker (1991), Sinha & Goel (1996) and Mohamed (2001)** who confirmed the same conclusion.

Concerning the genetic analysis in certain wheat entries from the perspective of partial resistance, the obtained results indicated that most of the selected parents exhibited disease reaction ranged from moderate susceptible to susceptible with the exception of Gemmeiza-3 which showed moderate resistant response. The reaction of $F_1$ plants in 10 crosses rated moderate susceptible to susceptible except the 3 crosses *i.e.* (Giza 167 × Sakha 61), (Giza 167 × Gemmeiza-3) and (Sakha 8 × Gemmeiza-3) which displayed resistant. This behaviour is considered to be a criterion to the dominance direction. It could be concluded that dominance in most of the crosses tend to the side of susceptibility and to the side of resistance in the later 3 crosses. Similar results were reported by **Orlyuk & Lavrinenko (1985) and Shehab El-Din, *et al.* (1991)** who indicated the direction of dominance in $F_1$ plants in their crosses.

In relation to the $F_2$ plants, the obtained results indicated the presence of transgressive segregation to stem rust resistance within the crosses. These segregations exceeded both of the tested parents in susceptibility and/or resistance. Resistance in most of the tested crosses was controlled by two gene pairs, with the exception of the two crosses *i.e.* (Giza 167 × Sakha 69) and (Sakha 8 × Gemmeiza-3) in which resistance was governed by single recessive gene and single dominant gene, respectively. These results were coincide with the finding of **Biffen (1905) and Shahin (1998)** who confirmed the presence of single or two gene pairs controlling the resistance.

The genetical analysis of $F_2$ plants from the perspective of mode of gene action gave evidence to the presence of complementary genes governing the resistance to stem rust in the crosses *i.e.* (Giza 167 × Sakha 8) and (Sakha 8 × Sakha 69). This conclusion was driven from the segregation ratio 9:7 (R : S). On the other hand, the presence of the modified ratio 13:3 or 3:13 in five crosses, will give us the ground to postulate presence of inhibitory genes controlling the resistant in such crosses.

Likewise, the presence of the segregation ratio 15:1 in the cross (Sakha 69 × Gemmeiza-3) gave controlling stem rust resistance in this cross.

The presence of the segregation ratio 3:1 or 1:3 confirmed that resistance to stem rust is a simple inherited character governed by one gene pair in the two crosses (Giza 167 × Gemmeiza-3) and (Giza 167 × Sakha 69). These results run in parallel lines with those of **Biffen (1905), Knott and Weller (1988), McIntosh (1988), Bolate & Roelfs (1991) and Shehab El-Din, *et al.* (1991)** who confirmed the same conclusion about the simplicity of resistance of stem rust as an inherited character or polygenic one controlled by many gene pairs as well as environmental conditions. These responsible genes may be dominant or recessive.

## Summary

Wheat (*Triticum aestivum* L.) is one of the important food crops in the world and in Egypt. During it's life, wheat is subjected to the attack of numerous diseases particularly the rusts, which play an active part in mass production. Wheat stem rust is one of the common rust diseases in Egypt.

The presented results indicated prevalence of stem rust in the Northern governorates of Egypt approximately *ca* 10% to 40 %. Six and five physiologic races of *Puccinia graminis tritici* could be identified during 1998/99 and 1999/2000, in this respect. Race no. 11 was the more frequent one.

The study gave evidence to community of the virulence formula *i.e.* 26, $Gt^+$, 9e, 36 and the formula 26, $Gt^+$ as the more frequent ones during the two successive seasons. However *Sr* 26 followed by *Sr* 9e, *Sr* $T_{t-1}$ and *Sr* 11 were the most effective genes during the two seasons in respect.

The application of the modern nomenclature system for rust races resulted in the community of races *i.e.* RTK and TTT which were correlated with the dominance of *Sr*'s: 9e, 36, then *Sr* 8a during 1998/99. On the other hand, races *i.e.* RKT, RFT, MKT, MFT were dominant during 1999/2000 and were relevant to *Sr*'s: 9e, 11, 6 and 21 so these genes were considered to be more effective during 1999/2000. Conversely, all of the tested races were virulent to *Sr* 9b indicating it's defeating.

The results obtained from gene postulation test originated from the comparisons of certain commercials and *Sr*'s against 30 stem rust isolates, gave evidence to the presence of at least 3 *Sr*'s

within the genetic background of Sakha 61. However, the cultivar Gemmeiza-7 may comprise 13 *Sr*'s.

The rest of entries ranged between the two limits. Likewise, it was concluded from these results that *Sr* 36, *Sr* 30, *Sr* 29 followed by *Sr* 7b, 8a have the community within our commercials, however, *Sr*'s: $T_{t.t}$, *Sr* 26, *Sr* 21, *Sr* 9e were less frequent, in anther term, the local cultivars lacked these genes to be incorporated.

As regard to the evaluation of certain commercials, the present results gave evidence to the distinction of the slow rusting varieties by smaller size of both pustule and colony in addition to prolonged incubation periods, comparing with the fast rusters. On the other hand, the fast rusters were characterized by higher ratios of erupted pustules when inoculated with race 15. The situation was quite different with race 11.

The results of anatomical studies gave explanation to the distinction of slow rusting varieties by increase thickness cuticle, epidermis and outer walls as compared to those varieties of fast rusters. On other hand, the sclerenchyma areas were more extended in the slow rusters, however the collenchyma were more available in the fast rusters.

Regarding the root weights as affected by stem rust infection, the obtained results gave evidence the reduction in such weights in relation to leaf cutting. The more affected variety by this deleterious effect was Giza 160 which was dramatically affected by rust infection, leaf cutting, then untreated plants (control) in respect. On contrast Sakha 61 was the less affected one.

Regarding the crop and disease evaluation, the obtained results indicated that Giza 168 followed by Giza 157 exhibited the least AUDPC during the two seasons. However, the reverse was true with Sohag-3. The highest 1000 k.w was recorded with Giza 165, however the reverse was observed with Gemmeiza-3 during the two seasons. The least 1000 k.w under infection stress was recorded with Sakha 8. During 1999/2000 the highest 1000 k.w was recorded with Giza 164, however the reverse was noticed in Sakha 8.

The results of 10 spike weight, run in parallel lines with those of 1000 k.w in the same trend, except few exceptions.

As regard to the genetic analysis, the obtained results indicated that the crosses amongst 6 parents revealed the presence of 15 crosses semi diallel. For experimental consideration 5 were excluded and 10 were appointed.

It could be concluded that:

1- Disease reaction within parents ranged between MS to S with the exception of Gemmeiza-3 and Giza 168 which rated 10R to 20R.

2- $F_1$ reaction ranged between MS to S indicating that susceptibility was the direction of dominance, with the exception of 3 crosses which tend to the resistance side.

Results of genetic analysis of $F_2$ plants indicated the presence of transgressive segregation. Generally, resistance was controlled by two gene pairs in most of these crosses, except two, in which resistance was controlled by two dominant genes in one and two recessive genes in the other.

According to the modification in segregation ratios, the results could be explained by presence of complementary genes in two crosses and duplicated genes in six crosses. However no segregation for susceptibility was observed in one cross.

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# ARABIC SUMMARY

## الملخص العربى

# دراسات على مرض صدا الساق الاسود فى القمح

يعتبر القمح من أهم محاصيل الغذاء فى العالم وفى مصر ، ويتعرض هذا المحصول اثناء نموه للعديد من الأمراض أهمها الأصداء والتى تلعب دوراً هاماً فى كم الانتاج . ويعتبر صدأ الساق من أهم الاصداء الشائعة فى مصر. ويتعلق هذا البحث بدراسة صدأ الساق فى مصر وطرق مقاومته .

**ويمكن تلخيص أهم النتائج فى النقاط الاتية:**

- قد بينت نتائج الدراسة انتشار هذا المرض فى المحافظات الشمالية بمصر بنسبة تتراوح ما بين ١٠ ، ٤٠ % وقد امكن تعريف ست سلالات فسيولوجية من المسبب المرضى له فى موسم ١٩٩٩/٩٨ وخمس سلالات فى موسم ٢٠٠٠/٩٩ وكان أكثر هذه السلالات شيوعاً على مدى الموسمين هى السلالة رقم ١١ . كما بينت الدراسة ايضاً أن الصيغة العداونية *Sr*'s: 26, Gt$^{+}$,9e, 36 والصيغة *Sr* 's: 26, Gt$^{+}$ هما اكثر الصيغ تكراراً على مدى الموسمين وفيما يتعلق بكفاءة الجينات فقد كان الجين *Sr* 26 اعلاها كفاءة واعقبه *Sr* 9e فى الموسم الاول والجين $T_{t-1}$ ثم *Sr* 11 فى الموسم التالى .
- وطبقاً لتطبيق نظام لتسمية الحديثة دلت النتائج على شيوع السلالتين TTT ثم RTK فى الموسم الاول وهذه السلالات قد ارتبط بها سيادة الجينات *Sr* 9e, *Sr* 36 ثم *Sr* 8a فى موسم ١٩٩٨/٩٩ بينما سادت السلالات RKT, RFT, MKT, MFT ولم تكن هذه السلالات عدوانية على الجينات *Sr* 9e, *Sr* 11, *Sr* 6, *Sr* 21 وبمعنى آخر فإن هذه الجينات تعتبر جينات مقاومة ضد المرض هذا الموسم كما بينت الدراسة أن كل السلالات المعرفة كانت عدوانية على الجين *Sr* 9b مما يدل على عدم فعاليته.
- كما دلت نتائج التوقع الجينى المشتقة من مقارنة الاصناف التجارية والاصناف الاحادية الجين ضد ٣٠ عزلة فطرية داخل السلالات على احتمال احتواء (الصنف سخا ٦١) على ٣ جينات مقاومة ، بينما احتوى الصنف (جميزة ٧)على ١٣ جين وتراوحت الاصناف الاخرى بين هذين الحدين .

وقد دلت نتائج التوقع الجينى على سيادة الجينات الآتية داخل الاصناف المصرية وهى : *Sr*'s: 36, 30, 29 ثم *Sr* 7b, *Sr* 8a بينما كان أقلها شيوعاً داخل الاصناف *Sr* Tt-1, *Sr* 26, *Sr* 21, *Sr* 9e .

- وفيما يتعلق بتقييم بعض الاصناف التجارية ، فقد دلت النتائج أن الاصناف بطيئة الصدأ قد تميزت بصغر حجم البثرات وحجم المستعمرات اقل من تلك السريعة الصدأ مع تميز الاول بطول نسبى فى فترة الحضانة – ومن جهة أخرى تميزت الأصناف السريعة الاصداء بزيادة نسبة البثرات المنفجرة وقلة نسبة البثرات غير المنفجرة مع السلالة رقم ١٥ بينما أختلف الوضع قليلاً فى هذه الصفة مع السلالة ١١ .
- وفيما يتعلق بالدراسات التشريحية فقد دلت النتائج على تميز الاصناف البطيئة الصدأ بزيادة سمك الكيوتيكل وزيادة طبقة البشرة والجدر الخارجية مقارنة بالاصناف السريعة الصدأ . ومن ناحية أخرى تميزت الاولى بزيادة مساحات الخلايا الاسكلرنشيمية سواء فى القطاعات التشريحية التى اجريت فى السيقان أو الاوراق فى (طور البادرة أو البلوغ) . وبالعكس لوحظ تميز الاصناف السريعة الصدأ بزيادة نسبة الخلايا الكولنشيمية.
- ودلت النتائج ايضاً على وجود فروق معنوية فى اوزان الجذور فى طور البادرة كتأثير منعكس للاصابة بصدأ الساق مقارنةً بعملية قطع الاوراق على مراحل ثابتة .
- وفيما يتعلق بالتقييم المحصولى والمرض دلت النتائج على أن الصنف جيزة ١٦٨ واعقبه الصنف جيزه ١٥٧ قد تميزا بأقل مساحة تحت منحنى المرض خلال موسمى الدراسة . وسجل العكس على الصنف سوهاج ٣ وكان اعلى نقص فى وزن الف حبة فى المعاملات المعدية والمحمية فى موسم ١٩٩٩/٩٨ قد سجل على الصنف جيزة ١٦٥ وأقل نقص فى هذا الوزن قد سجل على الصنف جميزه ٣ (فى كلا الموسمين) وسجل أقل وزن ١٠٠٠ حبة فى المعاملة المعدية مع الصنف سخا ٨ . وفى الموسم التالى سجل اكبر وزن للالف حبه مع الصنف جيزه ١٦٤ وسجل العكس مع سخا ٨ . وجرت نتائج التقييم على اساس وزن ١٠ سنابل تقريباً فى نفس الاتجاه السابق .

**بالنسبة للتقييم الوراثى** ، فقد تم اجراء تهجينات Semi diallel بين ستة آباء نتج عنها ١٥ هجين استبعد منهم خمسة وتواصلت الدراسة مع ١٠ هجن . وذلك لاعتبارات تجريبية .

- وقد دلت نتائج التقييم الوراثي على الاتي :-

١- تراوحت الاصابة فى معظم الآباء ما بين MS – S باستثناء الصنف جميزه ٣ الذى سجل 20 R – 10 R .

٢- كان تفاعل الجيل الاول $F_1$ لهذه الهجن متراوحاً بين (MS – S) فيما عدا ٣ هجن اعطت تفاعل ينحصر بين (10R – 20R) ولهذا علاقه باتجاه السيادة حيث يمكن القول بأن السيادة كانت فى اتجاه القابلية للاصابة ما عدا هذه الهجن الثلاثة. حيث لوحظ فى نباتات الجيل الاول للهجين رقم ٥ (جيزه ١٦٧ × سدس ٨) أن شدة الاصابة المرضية تمثل الاب الاعلى فى الاصابة وهذا يوضح السيادة التامة Complete dominance لطرز الاصابة.

٣- أما التحليل الوراثى لنباتات الجيل الثانى $F_2$ فلوحظ فيه بعض الانعزلات الفائقة التى تزيد مقاومتها عن الاب المقاوم أو تزيد قابليتها للاصابة عن الاب القابل للاصابه . وكانت المقاومة فى اغلب هذه الهجن يحكم بزوجين من الجينات باستثناء هجينين كانت المقاومة فيهما تحكم بزوج واحد من الجينات هذا الزوج كان سائداً فى احدهما ومتنحياً فى الأخر وهما الهجين رقم ٢ ، والهجين رقم ٨ حيث كانت النسبة المتوقعه لتلك الهجن هى ٣ : ١ وفى الهجينين رقم ١ والهجين رقم ٦ كانت الأباء قابلة للاصابة الا انه اظهرت النباتات فى الجيل الثانى الفعل المقاوم ويرجع ذلك الى التأثير المكمل Complementary effectحيث كانت النسبة المتوقعة لهذه الهجن ٩ : ٧ .

كما دلت النتائج ايضاً أن التفاعل الجينى فى الجيل الثانى بناءاً على التحورات فى النسب الانعزالية دلت على وجود جينات متضاعفة Duplicated فى هجين رقم ١٠ وجينات مثبطة Inhibitory فى باقى الهجن .

بسم الله الرحمن الرحيم

" قالوا سبحانك لا علم لنا إلا
ما علمتنا انك انت العليم
الحكيم "

صدق الله العظيم

البقرة - اية ٣٢

١٨٠

جامعة طنطا
كلية الزراعة – كفرالشيخ
قسم النبات الزراعى

# دراسات على مرض صدأ الساق الأسود فى القمح

رسالة علمية مقدمة من

**عاطف عبدالفتاح محمد السيد**

بكالوريوس فى العلوم الزراعية ــ أمراض نبات
جامعة طنطا – عام ١٩٨٩

للحصول على

**درجة الماجستير فى العلوم الزراعية**

(أمراض نبات )

**قسم النبات الزراعى**

**كلية الزراعة ـ جامعة طنطا**

**كفرالشيخ**

**٢٠٠٢**