International Journal of Education and Research
Vol. 1 No. 1 January 2013

MALT QUALITY AND STEM RUST RESISTANCE OF SELECTED BARLEY GENOTYPES IN KENYA

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ABSTRACT

Stem rust, caused by (*Puccinia graminis* f.sp. *tritici)* is a major disease of wheat in Kenya. The disease was previously contained by the rpg1, sr31, 24 and 36 genes for resistance that were incorporated in the genotypes of barley and wheat grown in Kenya. In 1999, a new race Ug99 was detected in Uganda; is now virulence to these genes. The new race spread rapidly and in 2001, stem rust monitoring in Kenya detected isolates of Ug99. Most of the work on wheat shows susceptibility. Although barley is an important crop affected by stem rust limited work has been done to it. Twenty barley cultivars locally Kenya and imported from International Centre for Agriculture Research in Dry Area (ICARDA) were screened in controlled greenhouse environment and in the field with isolate of *Puccinia graminis* f.sp. *tritici*. The germplasms showed varying levels of resistance to stem rust. At seedling stage, the infection levels ranged from 0 to 2, except in ICARDA- 09 and ICARDA- 11 that showed infection types 3 and 3,4 respectively. At adult plant stage, genotypes ICARDA- 01, Nguzo and Karne were moderately resistant while the rest were susceptible or moderately susceptible. In the field, the new line 1512-5 showed the highest severity of 93% in season 1, with Sabini having the highest severity of 30% in the second season; Nguzo had the lowest disease severity of 16% and 5% in season 1 and 2 respectively. The highest reduction in percent germination (54.1% and 38.3%) was recorded in 1385-13 and ICARDA- 10 in season 1and 2 respectively. The highest loss (9.00 %) in protein content was observed in Sabini in season 1 and a loss of 4.0 and 16.3% in zeleny content was noted in season 1 and 2 respectively. From the results in this experiment most of the Kenyan grown cultivars were susceptible to the new race of stem rust. This emphasizes the need for regular monitoring of the stem rust pathogen, in particular isolates in the variable Ug99 lineage, as well as continued resistance breeding. The study has demonstrated the pathogenicity of PgtUg99 to barley despite the fact that it poses a great threat to wheat production in the world.

KEY WORDS: Stem rust, Barley, Resistance, Ug99, *Puccinia graminis* f. sp. *tritici*, infection type.

INTRODUCTION

Stem rust caused by *Puccinia graminis* f.sp *tritici***,** Eriks. and E. Henn. is one of the most important plant diseases in Kenya. In wheat, the disease was previously contained through the use of genetic resistance resulting from genes such as Sr31 (KARI, 2005b). In 1999 and 2001 a new race Ug99 with virulence to stem rust resistant cultivars, was detected in Uganda and Kenya respectively (Wanyera *et al*., 2006; Pretorius *et al*., 2000). The Stem rust race Ug99 can cause up to 100% yield loss of wheat.

Efforts are now geared towards searching for alternative sources of resistance. Barley is an important cereal crop grown for malt and as livestock feed. It is one of the crops that is affected by the disease. Preliminary work indicates that the Stem rust race Ug99 is virulent to Midwestern barley cultivars carrying the durable stem rust resistance gene *Rpg1* (Steffenson and Jin, 2006). An experiment was carried out to determine the performance of selected barley genotypes from Kenya and ICARDA to the new race of stem rust Ug99.

MATERIALS AND METHODS

Site description

The experiment was carried out at the Kenya Agricultural Research Institute (KARI) -Njoro located at 0^0 20'S 35^0 56'E and at 2185 meters above sea level. The site receives an average rainfall of 939 mm per annum, with a mean temperature range of 9.5^0C to 24^0C. It falls within the agro-ecological zone III and the soils are predominantly *mollic Andosols* (Jaetzold and Schmidts, 1983). The site represents the optimal conditions for the development of stem rust disease hence it is described as a 'hot spot' for stem rust in Kenya (Roelfs *et al*., 1992).

Germplasm

Twenty barley germplasm from Kenya and ICARDA were screened (Table 1).

Table 1 : Type and source of barley germplasm used in the experiment

Genotypes code/ Name	Selection History	Source
ICARDA- 01	CBSS99MOO39IT-H-IM-IY-IM-IY-OM	ICARDA
ICARDA- 02	CBSS99MOO317T-AH-2M-IY-IM-IY-OM	ICARDA
ICARDA- 03	CBSS00YOO113T-A-OY-OM-2Y-OM	ICARDA
ICARDA- 04	CBSS99MOO429T-L-IM-IY-OM	ICARDA
ICARDA- 05	CBSW99WMOOO95T-B-IM-IY-IM-OM	ICARDA
ICARDA- 06	CBSS00YOOO48S-OY-OM-2Y-OM	ICARDA
ICARDA -07	CBSSOOYOO475T-O-OY-OM-2Y-OM	ICARDA
ICARDA- 08	CBSSOOYOO236T-E-0Y-OM-2Y-OM	ICARDA
ICARDA- 09	CBSS99MOO349T-F-3M-IY-IM-OM	ICARDA
ICARDA- 10	CBSS99MOO468T-H-IM-IY-OM	ICARDA
ICARDA -11	CBSSOOYOO479T-D-OY-OM-IM-OM	ICARDA

ICARDA -12	CBSW98WOOO54S-BY-2M-IY-2M-IY-OM	ICARDA
ICARDA- 13	CBSS99MOO315T-F-IM-F-IM-IY-IM-IY-OM	ICARDA
ICARDA- 14	CBSSOOYOO225T-C-OY-OM-2Y-IM-OM	ICARDA
ICARDA- 15	CBSSOOYOO278D-G-OY-OM-2Y-OM	ICARDA
1385-13	-	KENYA
NGUZO	-	KENYA
1512-5	-	KENYA
KARNE	-	KENYA
SABINI	-	KENYA

Stem Rust Isolate preparation

The spores used for inoculation were collected from experimental plots in KARI-Njoro. The urediniospores were collected using a portable powered suction pump (Hoover Model, 2944B) ® from wheat cultivar Chozi. In the laboratory, the inoculum was pre-tested on differential hosts in the greenhouse according to Roelfs and Martin (1989) and confirmed to be those of PgtUg99. The isolate was inoculated onto seedlings of the susceptible wheat cultivar chozi having gene Sr31 to generate large quantities of urediniospores. The Urediniospores were suspended in distilled water where light mineral of oil- (tween 20 solution) was added and the suspension sprayed onto the plants using a small bowler-atomizer. The plants were then kept in a dark humidity chamber overnight before taking them to clear plastic chambers in the greenhouse to prevent contamination resulting from the movement of urediniospores. Urediniospores were harvested from sporulating pustules at 14 and 21 days after inoculation using a cyclone spore collector and then dried for 2 to 3 days over silica gel in the laboratory (McIntosh *et al*., 1995).

Greenhouse Experiment

Infection type at Seedling stage

Diammonium Phosphate (18%N and 46% P_2O_5) at an equivalent rate of 50Kg/ha was thoroughly mixed with forest soil that had been autoclaved at 121^0C and 15 pounds pressure for one hour (Welty *et al.,* 1992). The soil was then filled into 20- cm plastic pots where 10 seeds of each of the 20 barley germplasm were sown. The pots were then arranged in a Completely Randomized Design (CRD) with three replications.

After emergence, the plants were thinned to eight then inoculated with the urediniospores 10 days after germination. The urediniospore suspension (1mg of urediniospore per 100ml of distilled water) was mixed with 4 drops of tween 20, surfactant using a small bowler- atomizer and inoculated on the seedlings. The inoculation involved uniform spraying of the upper and lower leaf surfaces of individual plants. Immediately after inoculation the seedlings were incubated for 24 hours in a dark dew chamber kept moist by frequently spraying with water to maintain humidity of 80-100%, and temperatures

between 16^0C and 22^0C. The seedlings were transferred to the greenhouse after incubation. For the first two hours, the leaves were sprayed with water for 15 minutes at an interval of 30 minutes using an atomizer. Temperature of 22-30^0C was there after maintained in the green house, following the procedure by McIntosh *et al*. (1995). Fourteen days after inoculation the seedlings were assessed for disease severity according to Stakman *et al.* (1962) scale for stem rust.

Reaction type to stem rust at adult plant stage

Forest soil that had been autoclaved at 121^0C and 15 pounds pressure for one hour (Welty *et al.*, 1992) was thoroughly mixed Diammonium Phosphate (18%N and 46% P_2o_5) at an equivalent rate of 50Kg/ha. The soil was then filled in the 20cm diameter plastic pots before 10 seeds of each of the 20 barley germplasm were sown per pot. Two weeks after emergence, the plants were thinned to eight. The pots were placed on trays with gravel and watering done every other day for 30 minutes. At flag leaf stage the plants were inoculated with urediniospores suspension (1mg urediniospores/ 100 ml of distilled water plus 5 drops of tween 20 surfactant). The urediniospore suspension (0.5ml per plant) was injected into elongating stems using a syringe and a hypodermic needle (Welty *et al*., 1992), and then placed in a dark dew chamber over night. The plants were then moved to the greenhouse and placed on a bench where a spray of water was applied on the leaves every 15 minutes for 2 hours to maintain temperature between 22-30^oC. The experiment was laid out as a Completely Randomized Design (CRD) with three replications. Fourteen days after inoculation and weekly thereafter, the disease reaction rating based on the size of the pustules and associated necrosis or chlorosis as described by Roelfs *et al*. (1992) was done.

Field Experiment

Stem rust severity and infection type

Twenty barley cultivars (Table, 1) were screened for resistance to stem rust disease in the field and evaluated for the losses in quality associated with stem rust Ug99. The cultivar were sown in plots of 3m length at spacing of 20 cm, at seed rate of 125 kg/ha. The experimental design was Randomized Complete Block Design (RCBD) laid out in split plot arrangement. The main plots consisted of fungicide (protected and unprotected). The fungicide used was tebuconazole (folicur) at the rate of 0.75l/ha at an interval of 21 days starting from the stem elongation stage (Zadoks *et al.*, 1974). The subplots consisted of the 20 barley cultivars. The experiment was replicated three times. Susceptible wheat cultivars, Chozi was planted perpendicular to test plots in the middle of the 1-m pathways on both sides of experimental plots to serve as spreader. All the agronomic practices were done according to the recommendations (Acland, 1971). The spreader rows were inoculated with *P. g. tritici* pathotype TTKSK at the early jointing stage by injecting an aqueous suspension of urediniospores into the hollow culm of plants at 0.75-m intervals along each spreader.

When 50% of the plants had reached heading, infection type responses based on Roelfs *et al.* (1992), McIntosh *et al.* (1995) and disease severities as described by Peterson *et al.* (1948) were recorded stage

at an interval of 14 days until hardening stage. Quality of barley was detremined based on germination percentage as described by (American Society of Brewing Chemists) ASBC Barley 3C, IOB, and EBC procedure (ASBC, 2004). An Infratec 1241® Grain Analyzer was used to determine protein, starch, zeleny and glutan content of the grains from the treated and untreated plots.

RESULTS AND DISCUSSION

Disease Infection Levels of Stem Rust in the Greenhouse

The germplasm showed varying levels of resistance to stem rust. At seedling stage, the infection levels ranged from 0 to 2, except in ICARDA- 09 and ICARDA- 11 that showed infection types 3 and 3,4 respectively (Table, 2). In adult plant reaction, 60% of the population was susceptible, 20% moderately susceptible, 10% moderately susceptible to moderately resistant and 10% moderately resistant. Genotypes ICARDA- 01 and ICARDA- 14 were moderately resistant (MR) while, Nguzo was resistant to moderately resistant (R -MR). Karne was however moderately resistant to moderately susceptible reaction (MR - MS). Fox and Harder (1995) noted that terminal disease severities were a reliable indicator of resistance to stem rust in wheat and barley. Barley germplasm that showed the highest final disease percent were considered very susceptible. The genotypes that showed some resistance at adult stage may contain a major single gene that remained resistant at seedling and at adult plant stage or they may have minor genes that are working together to reduce the disease (Roelfs *et al.*, 1992). The poor relationship in resistance at seedling stages may probably because the resistance was broken down at the later plant stage.

Table 2 : Seedling infection type and adult plant reaction of barley to PgtUg99 in the greenhouse

Genotypes code/ Name	Selection History	Seedling infection type[a]	Adult plant reaction[b]
ICARDA- 01	CBSS99MOO39IT-H-IM-IY-IM-IY-OM	;	MR
ICARDA- 02	CBSS99MOO317T-AH-2M-IY-IM-IY-OM	0	S
ICARDA- 03	CBSS00YOO113T-A-OY-OM-2Y-OM	0;	S
ICARDA- 04	CBSS99MOO429T-L-IM-IY-OM	0	S-MS
ICARDA- 05	CBSW99WMOOO95T-B-IM-IY-IM-OM	1	S
ICARDA- 06	CBSS00YOOO48S-OY-OM-2Y-OM	1	MS
ICARDA -07	CBSSOOYOO475T-O-OY-OM-2Y-OM	1	MS-S
ICARDA- 08	CBSSOOYOO236T-E-0Y-OM-2Y-OM	1	S
ICARDA- 09	CBSS99MOO349T-F-3M-IY-IM-OM	3	S
ICARDA- 10	CBSS99MOO468T-H-IM-IY-OM	0	S-MS
ICARDA -11	CBSSOOYOO479T-D-OY-OM-IM-OM	; 1	S
ICARDA -12	CBSW98WOOO54S-BY-2M-IY-2M-IY-OM	4, 3	S
ICARDA- 13	CBSS99MOO315T-F-IM-F-IM-IY-IM-IY-OM	; 0	S
ICARDA- 14	CBSSOOYOO225T-C-OY-OM-2Y-IM-OM	2	MR

ICARDA- 15	CBSSOOYOO278D-G-OY-OM-2Y-OM	2	S
1385-13	-	1	S
NGUZO	-	0	R-MR
1512-5	-	0, 2	S
KARNE	-	2	MS-MR
SABINI	-	1	S

[a] *Seedling infection type as described by Stakman et al. (1962). 0 - Immune, ; - Very resistant, 1- Resistant, 2- Moderately resistant, 3 - Moderately susceptible, 4 - Susceptible.*

[b] *Adult plant reaction based on modified cobb scale (Roelfs et al.,1992): R, resistant; MR, moderately resistant; MS, moderately susceptible; S, susceptible.*

Field Experiment

Disease severity

Disease pressure was higher in season 1 than in season 2 probably because of differences in environmental conditions (Roelfs *et al.*, 1992). Among the 20 genotypes that were evaluated for adult plant resistance, ICARDA-01, Nguzo and Karne were moderately resistant while the rest were susceptible or moderately susceptible (Table, 3). Genotype 1512-5 showed the highest (93%) severity in season 1, while Sabini had the highest (30%) severity in the season 2. Nguzo had the lowest disease severity of 16% and 5% in season 1 and 2 respectively. Jin *et al.* (1994) similarly found an interaction between host genotypes and rust pathotypes which was attributed to variation in environmental temperature.

Table 3 : Adult plant response of barley germplasm to infection and disease severity of PgtUg99 in the field

Genotypes code/ Name	Selection History	Season 1	Season 2
ICARDA- 01	CBSS99MOO39IT-H-IM-IY-IM-IY-OM	23*MR**	7MR
ICARDA- 02	CBSS99MOO317T-AH-2M-IY-IM-IY-OM	28S	6S
ICARDA- 03	CBSS00YOO113T-A-OY-OM-2Y-OM	56S	18S
ICARDA- 04	CBSS99MOO429T-L-IM-IY-OM	46S-MS	13MS
ICARDA- 05	CBSW99WMOOO95T-B-IM-IY-IM-OM	41S	13S
ICARDA- 06	CBSS00YOOO48S-OY-OM-2Y-OM	23MS	9MS
ICARDA -07	CBSSOOYOO475T-O-OY-OM-2Y-OM	40MS-S	16MS
ICARDA- 08	CBSSOOYOO236T-E-0Y-OM-2Y-OM	45S	16MS
ICARDA- 09	CBSS99MOO349T-F-3M-IY-IM-OM	53S	15S
ICARDA- 10	CBSS99MOO468T-H-IM-IY-OM	46MS	15MS
ICARDA -11	CBSSOOYOO479T-D-OY-OM-IM-OM	73S	13S

ICARDA -12	CBSW98WOOO54S-BY-2M-IY-2M-IY-OM	50S	15S
ICARDA- 13	CBSS99MOO315T-F-IM-F-IM-IY-IM-IY-OM	63S	21S
ICARDA- 14	CBSSOOYOO225T-C-OY-OM-2Y-IM-OM	20MS	6MS
ICARDA- 15	CBSSOOYOO278D-G-OY-OM-2Y-OM	36S	16S
1385-13	-	86S	16S
NGUZO	-	16R-MR	5MR
1512-5	-	93S	21S
KARNE	-	46R-MR	13MR
SABINI	-	63S	3OS

[*] *Disease severity scale from 0 to 100%, as based on Peterson et al. (1948)*

[**] *Infection type responses based on Roelfs et al. (1992), McIntosh et al. (1995)*

Effect on Malting Quality

Germination percent

Percent germination varied significantly with genotype and treatment. The highest germination was observed in treated plots implying that the disease significantly affected the germination potential of barley. Genotypes 1385-13 and ICARDA- 10 showed the highest (54.1% and 38.3% in season 1and 2) reduction in germination (Table, 4). The reduction in germination percent could be attributed to the low level of stored starch resutling from interfernce in the process of photosynathate partioning to the grain by the stem rust disease (Wiese, 1977). In malting barley the seed is required to germinate for production of malt (Briggs and Woods, 1993). The failure of barlely to germinate at an acceptable level, (>95 %), could introduce problems during malting process.

Starch content

The stem rust Ug99 epidemics significantly reduced the starch content of barley (Table, 5). Irrespective of season, the disease had the greatest effect on genotypes ICARDA- 03, ICARDA- 05 and Nguzo. Since the rust fungus is an obligate parasite, it derives the requirement from the host plant hence reducing the starch that can be stored. Pfeiffer *et al*. (1969) observed that glucose fed to rusted wheat leaves was utilized by the fungus. The ratio of carbon in respired Co_2 contributed by C_6 and C_1 from hexose substrates (the C_6: C_1 ratio) declines from about 0.5 in healthy tissue to 0.3 at sporulation in rusted tissue (Antonelli and Daly, 1966). The fungus utilizes available glucose, with reduced photosynthesis and increased respiration hence the total glucose available for storage as starch is reduced.

Table 4 : Effect of stem rust disease on germination of barley genotypes

Genotypes code/ Name	Selection History	Season1	Season2	
		Mean %Loss	Mean %Loss	Season Difference
ICARDA- 01	CBSS99MOO39IT-H-IM-IY-IM-IY-OM	20.4 ± 5.58^{c}	19.6 ± 7.18^{abcde}	**NS**
ICARDA- 02	CBSS99MOO317T-AH-2M-IY-IM-IY-OM	23.5 ± 9.93^{c}	19.1 ± 8.32^{abcde}	**
ICARDA- 03	CBSS00YOO113T-A-OY-OM-2Y-OM	17.6 ± 3.80^{c}	3.8 ± 1.99^{e}	**
ICARDA- 04	CBSS99MOO429T-L-IM-IY-OM	50.6 ± 8.94^{ab}	33.1 ± 7.70^{ab}	**
ICARDA- 05	CBSW99WMOOO95T-B-IM-IY-IM-OM	21.1 ± 4.07^{c}	15.9 ± 6.91^{bcde}	**NS**
ICARDA- 06	CBSS00YOOO48S-OY-OM-2Y-OM	16.5 ± 2.63^{c}	7.5 ± 4.61^{de}	**
ICARDA -07	CBSSOOYOO475T-O-OY-OM-2Y-OM	38.9 ± 12.42^{abc}	16.1 ± 1.10^{bcde}	**
ICARDA- 08	CBSSOOYOO236T-E-0Y-OM-2Y-OM	19.5 ± 10.16^{c}	8.4 ± 5.51^{de}	**
ICARDA- 09	CBSS99MOO349T-F-3M-IY-IM-OM	25.4 ± 8.17^{c}	10.6 ± 6.40^{cde}	**
ICARDA- 10	CBSS99MOO468T-H-IM-IY-OM	35.7 ± 13.48^{abc}	38.3 ± 5.09^{a}	**NS**
ICARDA -11	CBSSOOYOO479T-D-OY-OM-IM-OM	23.8 ± 7.88^{c}	8.7 ± 3.13^{de}	**
ICARDA -12	CBSW98WOOO54S-BY-2M-IY-2M-IY-OM	15.6 ± 8.08^{c}	12.1 ± 9.43^{cde}	**
ICARDA- 13	CBSS99MOO315T-F-IM-F-IM-IY-IM-IY-OM	19.5 ± 7.92^{c}	25.6 ± 3.40^{abc}	**NS**
ICARDA- 14	CBSSOOYOO225T-C-OY-OM-2Y-IM-OM	21.2 ± 5.55^{c}	2.6 ± 1.24^{e}	**
ICARDA- 15	CBSSOOYOO278D-G-OY-OM-2Y-OM	29.5 ± 11.16^{c}	2.7 ± 2.64^{e}	**
1385-13	-	54.1 ± 9.71^{a}	17.1 ± 4.98^{bcde}	**
NGUZO	-	34.5 ± 5.53^{abc}	17.1 ± 4.72^{bcde}	**
1512-5	-	24.9 ± 7.29^{c}	5.4 ± 1.80^{e}	**
KARNE	-	18.5 ± 14.67^{c}	28.8 ± 18.49^{abc}	**
SABINI	-	51.5 ± 7.82^{ab*}	29.8 ± 3.82^{abc}	**

*Means followed by the same letter in column are not significantly different at ($p \leq 0.05$).

***** or NS** means the genotype was significantly and not significantly different between season*

Table 5 : Effect of stem rust Ug99 on starch content of barley grains

Genotypes code/ Name	Selection History	Season 1	Season 2	Season Difference
		Mean % Loss	Mean % Loss	
ICARDA- 01	CBSS99MOO39IT-H-IM-IY-IM-IY-OM	0.4 ± 0.32^{b}	0.4 ± 0.05^{b}	**NS**
ICARDA- 02	CBSS99MOO317T-AH-2M-IY-IM-IY-OM	0.8 ± 0.21^{ab}	0.5 ± 0.34^{b}	**
ICARDA- 03	CBSS00YOO113T-A-OY-OM-2Y-OM	1.7 ± 0.29^{ab}	1.7 ± 0.44^{a}	**NS**
ICARDA- 04	CBSS99MOO429T-L-IM-IY-OM	1.0 ± 0.47^{ab}	1.0 ± 0.83^{ab}	**NS**
ICARDA- 05	CBSW99WMOOO95T-B-IM-IY-IM-OM	1.5 ± 0.51^{ab}	1.5 ± 0.38^{ab}	**NS**
ICARDA- 06	CBSS00YOOO48S-OY-OM-2Y-OM	0.9 ± 0.06^{ab}	0.6 ± 0.46^{ab}	**NS**
ICARDA -07	CBSSOOYOO475T-O-OY-OM-2Y-OM	0.5 ± 0.24^{b}	0.6 ± 0.27^{ab}	**
ICARDA- 08	CBSSOOYOO236T-E-0Y-OM-2Y-OM	0.4 ± 0.45^{b}	0.7 ± 0.19^{ab}	**NS**
ICARDA- 09	CBSS99MOO349T-F-3M-IY-IM-OM	0.6 ± 0.15^{b}	0.7 ± 0.26^{ab}	**NS**
ICARDA- 10	CBSS99MOO468T-H-IM-IY-OM	0.2 ± 0.16^{b}	0.5 ± 0.38^{ab}	**NS**

ICARDA -11	CBSSOOYOO479T-D-OY-OM-IM-OM	0.7 ± 0.21^{ab}	0.7 ± 0.42^{ab}	**NS**
ICARDA -12	CBSW98WOOO54S-BY-2M-IY-2M-IY-OM	0.8 ± 0.36^{ab}	0.8 ± 0.11^{ab}	**NS**
ICARDA- 13	CBSS99MOO315T-F-IM-F-IM-IY-IM-IY-OM	0.8 ± 0.21^{ab}	0.3 ± 0.39^{b}	**
ICARDA- 14	CBSSOOYOO225T-C-OY-OM-2Y-IM-OM	0.5 ± 0.10^{b}	0.4 ± 0.28^{b}	**NS**
ICARDA- 15	CBSSOOYOO278D-G-OY-OM-2Y-OM	1.1 ± 0.46^{ab}	1.1 ± 0.24^{ab}	**NS**
1385-13	-	1.1 ± 0.10^{ab}	1.0 ± 0.35^{ab}	**NS**
NGUZO	-	2.4 ± 2.02^{a}	2.4 ± 0.41^{a}	**NS**
1512-5	-	0.5 ± 0.47^{b}	1.1 ± 0.28^{ab}	**
KARNE	-	0.8 ± 0.41^{ab}	0.8 ± 0.73^{ab}	**NS**
SABINI	-	0.9 ± 0.69^{ab}	0.9 ± 0.51^{ab}	**NS**

**Means followed by the same letter in column are not significantly different at ($p \leq 0.05$)*

***** or NS** means the genotype was significantly and not significantly different between season*

The protein, zeleny and gluten content

Stem rust Ug99 significantly affected the protein and Zeleny content of barley. The effect varied in genotypes and seasons. The highest loss (9.00 %) in protein content was observed in Sabini in season 1 (Table, 6). A mean loss of 4.0 and 16.3% in zeleny content was noted in season 1 and 2 respectively (Table,7). A mean of 17.1 and 53.2% in Nguzo was noted in season 1 and 2 respectively. Sabini and Nguzo gave gluten loss of 8.1 and 16.3% in season 1 and 2 respectively (Table, 8). The fungus being an obligate parasite it utilizes the protein in the host for its structural growth and development. More frequently, the total protein of the host and parasite remain constant (Johnson *et al.*, 1968) or declines (Gassner and Franke, 1938). Much of the total protein may be in the developing fungus, especially at sporulation and thereafter, hence leaving little protein in the host cell and subsequently little in the grain storage.

Table 6 : Effect of stem rust Ug99 on protein content (%) of barley at Njoro

Genotypes code/ Name	Selection History	Season1	Season2	Season Difference
		Mean %Loss	Mean %Loss	
ICARDA- 01	CBSS99MOO39IT-H-IM-IY-IM-IY-OM	3.8 ± 0.73	9.4 ± 0.15^{abc}	**
ICARDA- 02	CBSS99MOO317T-AH-2M-IY-IM-IY-OM	2.2 ± 1.66^{b}	6.5 ± 2.06^{bc}	**
ICARDA- 03	CBSS00YOO113T-A-OY-OM-2Y-OM	6.6 ± 2.62^{ab}	19.4 ± 4.82^{abc}	**
ICARDA- 04	CBSS99MOO429T-L-IM-IY-OM	2.8 ± 0.91^{b}	32.0 ± 8.00^{ab}	**
ICARDA- 05	CBSW99WMOOO95T-B-IM-IY-IM-OM	1.7 ± 0.94^{b}	7.9 ± 3.89^{abc}	**
ICARDA- 06	CBSS00YOOO48S-OY-OM-2Y-OM	3.0 ± 1.58^{b}	4.2 ± 2.02^{c}	**
ICARDA -07	CBSSOOYOO475T-O-OY-OM-2Y-OM	1.7 ± 1.35^{b}	16.4 ± 1.00^{abc}	**
ICARDA- 08	CBSSOOYOO236T-E-0Y-OM-2Y-OM	6.5 ± 4.98^{ab}	9.8 ± 3.03^{abc}	**NS**
ICARDA- 09	CBSS99MOO349T-F-3M-IY-IM-OM	1.5 ± 0.58^{b}	14.6 ± 1.88^{abc}	**
ICARDA- 10	CBSS99MOO468T-H-IM-IY-OM	2.7 ± 0.27^{b}	4.8 ± 1.73^{c}	**NS**
ICARDA -11	CBSSOOYOO479T-D-OY-OM-IM-OM	2.6 ± 0.92^{b}	18.6 ± 5.18^{abc}	**
ICARDA -12	CBSW98WOOO54S-BY-2M-IY-2M-IY-OM	4.3 ± 1.28^{b}	6.4 ± 3.18^{bc}	**NS**

ICARDA- 13	CBSS99MOO315T-F-IM-F-IM-IY-IM-IY-OM	2.0 ± 1.30[b]	41.9 ± 14.79[a]	**
ICARDA- 14	CBSSOOYOO225T-C-OY-OM-2Y-IM-OM	2.1 ± 0.60[b]	29.2 ± 11.90[ab]	**
ICARDA- 15	CBSSOOYOO278D-G-OY-OM-2Y-OM	2.2 ± 1.58[b]	6.5 ± 1.57[bc]	**
1385-13	-	5.3 ± 0.99[b]	5.0 ± 3.15[bc]	NS
NGUZO	-	17.1 ± 15.18[a]	53.1 ± 16.71[a]	**
1512-5	-	3.2 ± 0.88[b]	16.2 ± 5.79[abc]	**
KARNE	-	5.1 ± 2.64[b]	7.9 ± 5.73[abc]	NS
SABINI	-	8.0 ± 2.54[ab]	16.1 ± 5.98[abc]	**

[*] Any two means in a column whose S.E. values overlap are not different at α = 0.05 by DMRT. [*]Means followed by the same letter in column are not significantly different at (p ≤0.05).

***** or NS** means the genotype was significantly and not significantly different between season*

Table 7 : Effect of stem rust Ug99 on Zeleny content (%) of barley

Genotypes code/ Name	Selection History	Season1	Season2	Season Difference
		Mean % Loss	Mean % Loss	
ICARDA- 01	CBSS99MOO39IT-H-IM-IY-IM-IY-OM	3.8 ± 0.73	9.4 ± 0.15[abc]	**
ICARDA- 02	CBSS99MOO317T-AH-2M-IY-IM-IY-OM	2.2 ± 1.66[b]	6.5 ± 2.06[bc]	**
ICARDA- 03	CBSS00YOO113T-A-OY-OM-2Y-OM	6.6 ± 2.62[ab]	19.4 ± 4.82[abc]	**
ICARDA- 04	CBSS99MOO429T-L-IM-IY-OM	2.8 ± 0.91[b]	32.0 ± 8.00[ab]	**
ICARDA- 05	CBSW99WMOOO95T-B-IM-IY-IM-OM	1.7 ± 0.94[b]	7.9 ± 3.89[abc]	**
ICARDA- 06	CBSS00YOOO48S-OY-OM-2Y-OM	3.0 ± 1.58[b]	4.2 ± 2.02[c]	**
ICARDA -07	CBSSOOYOO475T-O-OY-OM-2Y-OM	1.7 ± 1.35[b]	16.4 ± 1.00[abc]	**
ICARDA- 08	CBSSOOYOO236T-E-0Y-OM-2Y-OM	6.5 ± 4.98[ab]	9.8 ± 3.03[abc]	NS
ICARDA- 09	CBSS99MOO349T-F-3M-IY-IM-OM	1.5 ± 0.58[b]	14.6 ± 1.88[abc]	**
ICARDA- 10	CBSS99MOO468T-H-IM-IY-OM	2.7 ± 0.27[b]	4.8 ± 1.73[c]	NS
ICARDA -11	CBSSOOYOO479T-D-OY-OM-IM-OM	2.6 ± 0.92[b]	18.6 ± 5.18[abc]	**
ICARDA -12	CBSW98WOOO54S-BY-2M-IY-2M-IY-OM	4.3 ± 1.28[b]	6.4 ± 3.18[bc]	NS
ICARDA- 13	CBSS99MOO315T-F-IM-F-IM-IY-IM-IY-OM	2.0 ± 1.30[b]	41.9 ± 14.79[a]	**
ICARDA- 14	CBSSOOYOO225T-C-OY-OM-2Y-IM-OM	2.1 ± 0.60[b]	29.2 ± 11.90[ab]	**
ICARDA- 15	CBSSOOYOO278D-G-OY-OM-2Y-OM	2.2 ± 1.58[b]	6.5 ± 1.57[bc]	**
1385-13	-	5.3 ± 0.99[b]	5.0 ± 3.15[bc]	NS
NGUZO	-	17.1 ± 15.18[a]	53.1 ± 16.71[a]	**
1512-5	-	3.2 ± 0.88[b]	16.2 ± 5.79[abc]	**
KARNE	-	5.1 ± 2.64[b]	7.9 ± 5.73[abc]	NS
SABINI	-	8.0 ± 2.54[ab]	16.1 ± 5.98[abc]	**

[*] Any two means in a column whose S.E. values overlap are not different at α = 0.05 by DMRT. [*]Means followed by the same letter in column are not significantly different at (p ≤0.05)

***** or NS** means the genotype was significantly and not significantly different between season*

Table 8 : Effect of stem rust Ug99 on gluten content of barley

Genotypes code/ Name	Selection History	Season1	Season 2	Season Difference
		Mean % Loss	Mean % Loss	
ICARDA- 01	CBSS99MOO39IT-H-IM-IY-IM-IY-OM	2.4 ± 0.90^{bc}	3.7 ± 1.39^{b}	**
ICARDA- 02	CBSS99MOO317T-AH-2M-IY-IM-IY-OM	8.7 ± 5.05^{ab}	5.2 ± 2.14^{b}	NS
ICARDA- 03	CBSS00YOO113T-A-OY-OM-2Y-OM	5.4 ± 0.58^{abc}	3.0 ± 0.94^{b}	**
ICARDA- 04	CBSS99MOO429T-L-IM-IY-OM	5.7 ± 1.86^{abc}	8.9 ± 2.80^{ab}	**
ICARDA- 05	CBSW99WMOOO95T-B-IM-IY-IM-OM	3.4 ± 1.34^{bc}	2.2 ± 0.33^{b}	NS
ICARDA- 06	CBSS00YOOO48S-OY-OM-2Y-OM	5.8 ± 0.40^{abc}	2.2 ± 1.24^{b}	**
ICARDA -07	CBSSOOYOO475T-O-OY-OM-2Y-OM	4.3 ± 1.29^{abc}	1.8 ± 3.97^{b}	NS
ICARDA- 08	CBSSOOYOO236T-E-0Y-OM-2Y-OM	4.8 ± 1.70^{abc}	4.5 ± 1.31^{b}	NS
ICARDA- 09	CBSS99MOO349T-F-3M-IY-IM-OM	1.4 ± 0.76^{c}	4.0 ± 1.90^{b}	**
ICARDA- 10	CBSS99MOO468T-H-IM-IY-OM	5.5 ± 1.31^{abc}	5.6 ± 2.33^{b}	NS
ICARDA -11	CBSSOOYOO479T-D-OY-OM-IM-OM	3.2 ± 1.14^{abc}	4.6 ± 1.91^{b}	NS
ICARDA -12	CBSW98WOOO54S-BY-2M-IY-2M-IY-OM	3.5 ± 1.58^{abc}	3.8 ± 1.80^{b}	NS
ICARDA- 13	CBSS99MOO315T-F-IM-F-IM-IY-IM-IY-OM	1.5 ± 0.42^{c}	3.2 ± 1.70^{b}	NS
ICARDA- 14	CBSSOOYOO225T-C-OY-OM-2Y-IM-OM	2.0 ± 0.73^{c}	6.5 ± 3.45^{b}	NS
ICARDA- 15	CBSSOOYOO278D-G-OY-OM-2Y-OM	1.2 ± 0.51^{c}	2.0 ± 1.14^{b}	NS
1385-13	-	3.8 ± 0.90^{abc}	5.3 ± 0.51^{b}	**
NGUZO	-	9.8 ± 7.17^{a}	3.6 ± 2.25^{b}	NS
1512-5	-	4.0 ± 0.97^{abc}	5.4 ± 2.73^{b}	NS
KARNE	-	0.8 ± 1.45^{c}	5.0 ± 3.69^{b}	NS
SABINI	-	8.1 ± 2.62^{ab}	16.3 ± 7.7^{a}	NS

** Any two means in a column whose S.E. values overlap are not different at $\alpha = 0.05$ by DMRT. *Means followed by the same letter in column are not significantly different at ($p \leq 0.05$)*

***** or NS** means the genotype was significantly and not significantly different between season*

CONCLUSION

Most of the barley germplasms are susceptible to stem rust race PgtUg99. Most of the genotypes were resistant at seedling stage but were susceptible at the adult plant stage. Stem rust Ug99 epidemics affected the quality (germination, starch and protein aspects) of barley which is an important factor for malting hence threatening beer industry.

ACKNOWLEDGMENTS

Funding from the graduate school of Egerton University is gratefully acknowledged. The assistance of Dr. Gethi, Macharia, and Mr. Kamundia from the National Plant Breeding Centre Njoro, and

Mr. Sylvester Denda from East Africa Malting for providing Kenyan genotypes used in this study is also appreciated.

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