We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



6

Challenges of Fungicide Control on Wheat Rusts in Kenya

Wanyera, R.[1], Macharia, J. K.[2], and Kilonzo, S. M[3]
[1]*Kenya Agricultural Research Institute (KARI)-Njoro, P.O Private Bag, Njoro 20107,*
[2]*Egerton University, P.O Box 536, Egerton,*
[3]*Kenya Agricultural Research Institute (KARI)-Njoro, P.O. Private Bag, Njoro 20107, Kenya*

1. Introduction

Stem rust or black rust (caused by *Puccinia graminis* Pers. f. sp. *tritici* Erikss. & E. Henn.) is a serious wheat disease causing a decrease of wheat production in many areas of the world (Roelfs, 1978). The effective barberry eradication in the early 20th century and the infrequent occurrence of favourable temperature in Europe has resulted in a decline in importance of stem rust. Until recently, the disease has been under effective control through the wide spread use of resistant varieties (Jin, 2007). The re-emergence of a new virulent race TTKSK (Ug99) in Eastern Africa region (Pretorius et al., 2000), and the subsequent detection of its many variants in Kenya has rendered important commercial varieties susceptible (Jin, 2008). Wide-scale epidemics have been frequent, being recorded in 2004, 2005, 2006, 2007, 2008, 2009 and 2010. Fungicides sprays have become part of the production practice of wheat growers in Kenya, although many are not effective. The fungicides used for the control of wheat leaf diseases have increased costs of production, because of the multiple applications required to protect the crop before it matures. Unlike in other regions e.g. United States, Canada, Australia and South Africa (Table 1), there is currently no fungicide registered for the control of wheat stem rust in Kenya, this is because the effects of fungicide on loss prevention are poorly understood and data is limited (Wanyera et al., 2009). However, fungicides are used extensively by producers in other countries to control stripe and leaf rusts, but only a few are registered for the control of stem rust.

Many fungicides have been found to be effective at specific growth stages. Until recently, studies have indicated that up to one-third of applications may be too late for optimal effectiveness. Application timing is critical in managing stem rust. Stem rust activity needs to be closely monitored both in individual fields and across regions. This is because preventive applications consistently provide better results than applications made after disease infection has occurred. Unlike stripe and leaf rust, foliar fungicide applications targeting stem rust must be applied as soon as the disease is detected as opposed to targeting key yield determining leaves. It is important to note that, the severity of any disease is related to inoculum pressure, weather conditions and variety susceptibility (Cook et al., 1999). According to Milne et al. (2007) the fungicide choice and the timing of application are often poor in commercial crops. Sometimes, crops receiving up to three

Active ingredient	Trade names	Stem Rust	Stripe Rust	Leaf Rust
Flutriafol	Flutriafol 250 EC, Force, Impact, Jubilee	*	250-500 mL/ha	250-500 mL/ha
Flusilazole/ carbendazim	Punch Xtra 125/250 EC	*	400 mL/ha	400 mL/ha
Propiconazole	Aurora 250 EC, Bumper 250 EC, Prestige, Propiconazole 250 EC, Slipstream 250 EC, Tilt 250 EC, Tyrant 250 EC	500 mL/ha	250-500 mL/ha	150-500 mL/ha
Tebuconazole	Folicur 430 SC, Orius 430 SC, Stingray, Tebuconazole 430 SC	*	145-290 mL/ha	145-290 mL/ha
Triadimefon	Accord, Bayleton 125 EC, Slingshot, Triad 125 EC, Triadimefon 125 EC, Turret	*	500-1000 mL/ha	*
Azoxystrobin	Amistar 250 SC	*	300 mL/ha	300 mL/ha
Azoxystrobin + Cyproconazole	Amistar Xtra 280 SC	400-800 mL/ha	400-800 mL/ha	400-800 mL/ha
Azoxystrobin + Difenoconazole	Amistar Top 200/125 SC	*	500 mL/ha	500 mL/ha
Trifloxystrobin	Twist 500 SC	*	100 mL/ha	100mL/ha
Cyproconazole	Alto 100 SL	*	400 mL/ha	400 mL/ha
Propiconazole + Cyproconazole	Tilt Xtra 250 EC	500 mL/ha	250-500 mL/ha	250-500 mL/ha
Epoxiconazole	Opus 125 SC	*	800 mL/ha	800 mL/ha
Hexaconazole	Anvil 50 SC	*	480 mL/ha	480 mL/ha

* Denotes not recommended

Table 1. Foliar fungicides and recommended rates used to control rust diseases of wheat in Australia and South Africa

badly-timed sprays suffer as much disease as those untreated, suggesting that either the fungicides are applied too late or do not control the disease effectively. Research has shown that fungicides applied during the period from flag leaf emergence to ear emergence (GS 37-59) offer the best prospects for cost-effective rust control in wheat (Bradley, 2004).

The management of stem rust by growing resistant varieties is undoubtedly the most desirable method of control. However, fungicides have been used against various diseases of cereals for over 100 years. With the introduction of systemic fungicides in the 1970's, fungicides became an integral part of cereal crop production. They have become established as an essential input in the growing of cereals and it is not possible to grow a profitable crop of wheat in stem rust "hot-spot" areas without the application of fungicide (Wanyera et al., 2009). Despite global concerns and restrictions on chemical development and usage in food

production, such limitations have tended to give impetus to developments in fungicide chemistry and delivery systems (McDonald, 2006). This was synergised by the development of new fungicide classes with novel modes of action in the 1990's. These include the strobilurins, phenypyrroles, anilinopyrimides, phenoxyquinolines and other compounds that induce defence mechanisms in the plant (Knight et al., 1997).

The Eastern Africa epidemics of wheat stem rust due to race Ug99 of *Puccinia graminis* f. sp. *tritici* (Pretorius et al., 2000) have stimulated interest in the search for effective and economically sustainable chemicals to manage this disease. In recent past the efficacy of various fungicides to control stem rust has been reported (Mayfield, 1985; Rowell, 1985; Loughman et al., 2005 and Wanyera et al., 2009). Fungicides can play a major role in integrated management of stem rust disease before new varieties with effective host resistance are released. Currently only limited studies have been conducted to determine the effectiveness of foliar fungicides on stem rust severity and grain yield in the Eastern Africa region (Wanyera et al., 2009), and none on the usefulness of seed and fertilizer treatments for the control of stem rust (Dill-Macky & Roelfs, 2000). The lack of fungicides specifically labelled for the control of stem rust in Kenya has hindered the immediate release of recommendations for fungicide use to manage the disease.

1.1 Nature and recurrent of wheat rusts

The history of wheat production in Kenya has been mainly an account of attempts to control stem rust, *Puccinia graminis* Pers. f. sp. *tritici* Eriks. & E. Henn., using resistant varieties (Green et al., 1968). Further, little is known of the sources of variation of stem rust in East Africa. There is circumstantial evidence that some variation is due to somatic recombination of existing virulence (Harder et al., 1970). The early wheat growers were confronted by frequent stem rust epidemics; this necessitated the search for resistant varieties and chemicals to manage rust diseases. Wheat stem rust has been studied at Njoro, Kenya, since 1927 (Guthrie, 1966). Kenya's wheat growing areas are unique in that they lie within the Great Rift Valley which extends from Mediterranean region in the north to South Africa. There is a possibility of urediniospores being transported throughout this mega-region, which ensures the presence of a large reservoir of inoculum, but if there was little or no exchange of inoculum, it was thought possible to limit rust development in any one area by controlling agricultural practices. This was attempted earlier in Kenya, where alternate host of rust (*Barberry vulgaris* L.) does not function (Green et al.,1970) by discouraging double cropping (two crops a year) to decrease the movement of rust from one crop to the next. Before the current effects of climate change (global warming), wheat was planted at designated times of the year to make maximum use of rainfall while the crop was growing, yet be ready for harvest during a dry period. This has since changed with the unreliability and low amount of rainfall received in wheat belts, therefore farmers have resulted in planting wheat throughout the year (multi-cropping). It is common to find within a short distance crops of all growth stages, this ensures the availability of "green-bridges" for urediniospore production and continuous supply of inoculum for new crops. This coupled with rapid change in altitude in wheat growing areas; entails localised epidemics occurring in many areas in the country depending on the growing season forming a stem rust migration route, where the disease pathogen moves back and forth in these areas. Therefore, high host resistance to all races of the pathogen would be required to withstand sustained disease attack; otherwise to grow wheat under such conditions without an effective fungicide protection programme is a serious challenge.

Ecological conditions in Kenya favour cereal rust development. Most of the wheat-growing areas are located in highlands (1,800 to 3,000 meters above sea level) known as "hot-spot'' for the evolution and survival of new rust races (Saari & Prescott, 1985). The growing season extends over 12 months, temperature range from 18 to 30^{o}C, days are uniformly about 12.5 hours long, dews are heavy, and precipitation occurs frequently as showers during the main growing season. Stem rust survives on volunteers or other hosts including, barley *(Hordeum spp.)*, triticale *(xTriticosecale)* and other related grasses. Normally stem rust is more active in the warmer parts of the cropping season or in lower altitude areas compared to stripe rust and leaf rust. It has been observed that race Ug99 is equally aggressive in the high cool elevations (2,700-3,000 meters above sea level) of Kenya.

1.2 Resistance/susceptibility of current varieties

According to Reynolds and Borlaug (2006), about 25% of the world's wheat area is at risk from stem rust attack, accounting for an estimated 19% of global production. In Kenya, since 2002 virtually all the growing areas; experiences devastating stem rust epidemic every year. Extensive screening of thousands of global wheat varieties for resistance to Ug99 in key sites in Kenya and Ethiopia for the last five years, only about 5% have exhibited appreciable resistance (Table 2). This indicates the vulnerability of all the countries producing wheat to the new stem rust pathogen. In Kenya, for instance, all the commercial varieties have succumbed to race Ug99, the farmers are advised to grow moderately susceptible varieties, which need fungicide protection at the appropriate growth stages in order to harvest an economic yield.

Resistance/susceptibility group	Estimated area	
	million ha	%
Unknown	30.71	41.1
Susceptible	38.54	51.6
Moderately susceptible	1.73	2.3
Resistant	1.04	1.4
Moderately resistant	2.72	3.6

* Singh et al., 2008

Table 2. Estimated areas planted to wheat varieties in 18 African and Asian countries resistance/susceptibility grouping to Ug99, based on screening data 2005 and 2006 in Njoro, Kenya.

1.3 Diagnosing stem rust disease in wheat

Stem rust fungi has been changing continuously, producing new races. These races are detected when previously resistant variety becomes infected. Therefore, when a resistant variety is sown, the crop should be monitored for disease on regular basis. This should start around the 2nd node stage (GS 32) and continue to flag leaf (GS 39) (Peterson et al., 1948). The protection of the shoots is important in contributing to the yield and quality of wheat. In "hot-spot" areas such as Kenya where the crop is under constant bombardment by urediniospores throughout the year, disease scouting starts at seedling and continues up to grain-filling growth stage. High infections around head emergence have been reported to

cause significant yield losses (Barlett et al., 2002). It is important for the grower to be able to identify the disease early; however, this is not always possible without relevant skills for the correct disease identification, and rust severity assessment that are prerequisite to informed decisions on fungicide use. While fungicide treatment is meant to control the disease, there is evidence that some have been shown to have beneficial effect on the plants by delaying senescence, thereby prolonging the duration of the green-leaf area and increasing yield (Burgeno et al., 2000; Bertelsen et al., 2001). However, distinguishing between the yield grain because of disease suppression and yield grain because of any direct physiological effects is difficult in field experiments. Quantitative evidence in representative environments is not available (Niks & Lindhout, 2006). However, the yield improvements are economically important and cannot be overlooked.

1.4 Fungicides for controlling rusts

The best way to control stem rust is to use resistance varieties, which is universally accepted. But its practical implementation remains a scientific challenge, because the fungus that causes wheat stem rust disease is difficult to control due to its nature of constantly evolving and mutating into new races. It is also important to note that the level of resistance expressed by varieties to stem rust can be significantly different to the one expressed to leaf diseases. Alternative control measures might prove economically feasible if areas of potential loss were identified in time to reduce damage by application of effective fungicides. Fungicides have become an integral part of disease-management programmes on cereal crops in many countries of the world. Most of the fungicides currently used for stripe rust and other wheat leaf disease control are not registered for the control of stem rust in Kenya (Table 1). Therefore the choice of an appropriate chemical is difficult (Viljanen-Rollinson et al., 2006).

The use of appropriate fungicide is an effective but least employed method of rust management. Foliar fungicides can achieve economic control as long as they are applied at an early disease onset (Loughman et al., 2005). Early intervention reduces damage to the leaves, stem and transport system ensuring translocation of nutrients, and therefore proper filling of grains. Chemical control is more effective when rust diseases are identified on susceptible varieties early in the growing season. Their effectiveness depends on varietal susceptibility, level of infection and stage of crop growth at application. In fields planted with moderately resistant (slow rusting) or resistant varieties, a fungicide application may not be necessary even if some disease occurs. However, fields planted with moderately susceptible or susceptible varieties should be scouted regularly, and any sign of disease may warrant a fungicide application. Although it is not advisable to plant very susceptible varieties, if sown two or more applications may be necessary to achieve a moderate level of control. Yield and quality studies with fungicides on grains have documented other benefits including bigger grain size and better milling quality (Bartlett et al., 2002).

1.5 Foliar fungicides and thresholds

In Kenya, farmers who afford fungicides for stem rust control commonly use calendar-based fungicide spray schedules. Under heavy stem rust epidemics some farmers in wheat growing areas have been reported to apply as many as 5 times per crop cycle and sometimes they alternate contact and systemic compounds. In other crops, studies indicate that fungicide spray regimes should be tailored to host resistance than depending on blanket recommendation. But for stem rust where wheat resistance has broken down, fungicide

application should begin when the first rust pustule appears. This is repeated every 7 to 10 days for contact or 14 to 21 days for systemic fungicides depending on rain and temperatures. Carisse et al. (2009) have recommended the use of action thresholds for rapid and accurate classification of the incidence of apple scab on leaves, and aid in scab management decision making. It has also been suggested that, stem rust infection thresholds be established to correctly determine the level of resistance in varieties in order to reduce the amount of fungicide treatments. But to gather sufficient data for this purpose, a massive national variety resistance evaluation process, and monitoring of the pathogen virulence is needed. This is costly and takes time. Paveley et al. (2003) demonstrated that it is possible to predict fungicide efficacy of a two spray programmes from the performance of their component single spray. In a related study, Kromann et al. (2009) concluded that timing fungicide sprays based on rainfall thresholds could be used to control Potato Late Blight. However, in the case of wheat stem rust in Eastern Africa where there is continuous cropping throughout the season it is difficult to predict an epidemic. The threshold system is used as a guide for whether or not there is adequate disease pressure to justify fungicide application. Fungicides are beneficial only if rust is present at high levels and occurs early in the season to cause yield loss. Timing of application is critical in managing stem rust, whose activity needs to be closely monitored. Unlike stripe and leaf rust, foliar fungicide applications targeting stem rust must be applied as soon as the disease is detected. The more important times for application of foliar fungicides are usually flag leaf emergence (GS 37) and full boot (GS 45), the latter is considered the ideal timing for a single spray. A follow up spray may be necessary 3 to 4 weeks later, if conditions continue to favour disease development. Preventative applications consistently provide better results than applications made after disease infection has occurred.

2. Fungicide Case Studies in Kenya

The following is an assessment of commercial and two new foliar fungicides available in Kenya for efficacy against Ug99 pathogen. This article reports field experiments conducted under natural infection to determine the effect of foliar fungicides on wheat stem rust severity, grain yield, and 1,000-kernel weight.

2.1 Materials and methods

2.2 Commercial fungicides

Field experiments were conducted in 2005 and 2006 in three locations represented by trial sites at (1) Kenya Agriculture Research Institute (KARI) - Njoro (0^{o} 20′ S, 35^{o} 56′) at 2,185 meters above sea level (MASL), with mean minimum and maximum temperatures of 9.7 and 23.5^{o}C respectively, and mean average rainfall of 900 mm; (2) Eldoret (0^{o} 31′ N, 35^{o} 15′ E) at 2,180 MASL, with mean annual rainfall 1,250 mm with minimum and maximum temperatures of 12 and 23^{o}C, respectively; and (3) Mau-Narok (0^{o} 39′ S, 35^{o} 57′ E) at 2,900 MASL an annual rainfall with 1,200 to 1,400 mm, minimum and maximum temperatures of 6 to 14 and 22 to 26^{o}C, respectively.

Nine commercial fungicides labeled for the control of stripe rust, leaf rust, and other leaf diseases of wheat were evaluated for control of stem rust in field experiment. The experimental units were 8 row field plots of 9 m^{2} with an inter-row spacing of 20 cm. The cultivar was the widely grown bread wheat Duma, which is highly susceptible to stem rust. The cultivar is moderately resistant to stripe rust (*P. striiformis* Westend. f. sp. *tritici* Erikss.). A randomized complete block design with four replicates was used in all the locations. An

experimental seed-drill planter was used at a seeding rate of 100 g/plot. Planting was done on May 19 at KARI-Njoro, June 4 at Eldoret and August 22 at Mau-Narok in 2005. In 2006, the planting dates were May 18 at Eldoret, May 30 KARI-Njoro and September 19 at Mau-Narok (Table 3).

		2005			2006	
Activity, GS[Z]	KARI-Njoro	Eldoret	Mau-Narok	KARI-Njoro	Eldoret	Mau-Narok
Planting	19-May	4-Jun	22-Aug	3-May	18-May	14-Sep
Fungicide application						
GS 55	4-Aug	10-Aug	15-Nov	9-Aug	3-Aug	...
GS 65	18-Aug	26-Aug	30-Nov	23-Aug	18-Aug	...
GS 65	...	...	...	...	...	15-Dec
GS 73	...	...	...	...	...	2-Jan, 2007
Disease assessment						
GS 55	4-Aug	10-Aug	15-Nov	9-Aug	3-Aug	...
GS 65	18-Aug	26-Aug	30-Nov	23-Aug	18-Aug	8-Nov
GS 65	...	...	...	...	...	15-Dec
GS 73	...	...	...	...	...	2-Jan, 2007
GS 77	1-Sep	13-Sep	14-Dec	8-Sep	12-Sep	16-Jan, 2007
Harvesting	12-Nov	4-Nov	26, March, 2006	6-Nov	31-Oct	6-April, 2007

[Z]GS= growth stage

Table 3. Schedule on planting, fungicide application, disease assessment, and harvesting at Kenya Agricultural Research Institute (KARI)-Njoro, Eldoret and Mau-Narok location in Kenya

The experimental fields were fertilized with Di-ammonium phosphate (18% N,46% P, 0% K) at the recommended rate of 150 kg/ha at planting. A pre-emergence herbicide, Stomp 500 E (pendimethalin), labeled for weed control in wheat was applied soon after planting at 3 liters/ha. Buctril MC (bromoxynil +MCPA) labeled for control of broad-leaved weeds was applied at 1.25 liters/ha at growth stage GS 24 (tillering). Metasystox 250 EC (oxy-demeton-s-methyl) was applied at 0.5 liters/ha to control cereal aphids at GS 24 (tillering), GS 65 (flowering), and GS 73 (milk) Zadoks et al., 1974).

The commercial fungicides tested were : (1) epoxiconazole + carbendazim (Swing 250 EC), (2) cyproconazole 80 g/L + propiconazole 250 g/L (Artea 330 EC), (3) tebuconazole + tridimenol (Silvacur 375 EC), (4) tebuconazole (Folicur 250 EC), (5) trifloxystrobin + propiconazole (Stratego 250 EC), (6) epoxiconazole 125 g/L + carbendazim 125 g/L (Soprano C 250 EC), (7) tebuconazole (Orius 25 EW), (8) hexaconazole (Cotaf 5 EC), and (9) azoxystrobin 200 g/L + cyproconazole 80 g/L (AmistarXtra 280 SC) all at the rate of 1.0 L/ha. The untreated plots served as the control. The fungicides were applied using a knapsack sprayer at recommended water volume of 200 liters/ha at GS 55 (heading) and GS 65 (flowering) (Zadoks et al., 1974).

Stem rust severities based on modified Cobb scale (Peterson et al., 1948) were scored three times on whole plots at GS 55, 65, and 73 or 77 (late milk) before fungicide application and at two 14 to 18 day intervals following the application, according to the schedule in Table 1. However, the third reading at Eldoret in 2006 was delayed due to logistical problems. Area under the disease progress curve (AUDPC) was calculated by a computer program developed at the International Centre for Maize and Wheat Improvement (CIMMYT) that calculates the area of the curve created by the disease scores taken three times during the crop cycle (Tables 4, 5, and 6).

Every plot was harvested using a Hans-Ulrich Hege plot combine harvester (Saatzuchtmaschinen Hohebuch). Grain weight measurements were taken after harvest and cleaning at 13 to 14% moisture content. A sample of grain was taken from each plot for determination of kernel weight based on the weight of 1,000 grains (1,000-kernel weight). Data on disease severity, grain yield, and 1,000-kernel weight were analyzed according to the analysis of variance procedure using SAS Statistical package (PROC-ANOVA) (SAS Institute, Inc. 1999). Differences in treatment effect were compared at ($P \leq 0.05$) using the least significant difference test (Steel and Torrie, 1980).

2.3 New fungicides (Nativo 300 SC and Prosaro 250 EC)

Field experiments were conducted at two locations (KARI-Njoro and Mau-Narok) during the 2006 and 2007 growing seasons to assess the efficacy of two new foliar fungicides; viz. trifloxystrobin 100 g/L + tebuconazole 200 g/L (Nativo 300 SC) and prothioconazole 125 g/L + tebuconazole 125 g/L (Prosaro 250 EC) each applied at three rates; 0.6 L/ha, 0.75 L/ha, and 1.0 L/ha. Two standard fungicides; azoxystrobin 200 g/L + cyproconazole 80 g/L (AmistarXtra 280 SC) and tebuconazole (Folicur 250 EC), each applied at the rate of 1.0 L/ha for comparison and untreated plots served as the control. The field operations, disease assessment and data analysis was conducted as described in materials and methods section.

3. Results

3.1 Rust severity

In 2005, the onset of stem rust disease was early in the growing season at KARI-Njoro, resulting in a severe infection of 77.5% at GS 77 in the untreated plots. In the same year severity at Eldoret and Mau-Narok was moderate, 30.0 and 35.0%, respectively (Tables 4, 5, and 6). In 2006, disease severity in untreated plots was 28.8% at KARI-Njoro, 45.0% at Eldoret, and 40.0% at Mau-Narok (Tables 4, 5, and 6). There were no other diseases observed in the experimental plots.

3.2 Effect of fungicides on stem rust severity

In both 2005 and 2006, fungicide treatments for AUDPC were significant ($P \leq 0.05$) at KARI-Njoro. Differences in AUDPC for stem rust were observed among fungicides at Eldoret and Mau-Narok in 2006. In 2005, non significant ($P \geq 0.05$) effects of fungicide treatments for AUDPC were obtained at Eldoret and Mau-Narok (Tables 4, 5, and 6). AUDPC values indicated that AmistaXtra 280 SC, Orius 25 EW, Folicur 250 EC, and Silvacur 375 EC, reduced rust severity across the three locations.

The trend of reduction on stem rust severity was maintained after first and second fungicide application. However, the reductions were more pronounced in the latter. Overall,

www.intechopen.com

Table 4. Effect of fungicide on stem rust severity, area under disease progress curve (AUDCP), grain yield, and 1,000-kernel weight on wheat cv. Duma at Kenya Agricultural Research Institute - Njoro[u]

	2005								2006			
	MRS[v]				Grain yield[w]		TKW[x]		MRS[v]			
Treatment[y]	1st	2nd	3rd	AUDCP[z]	t/ha	G (%)	Wt. (g)	G (%)	1st	2nd	3rd	AU
Untreated	23.8a	57.5a	77.5a	709 b	0.6b	-	29.8d	-	10.3a	11.3a	28.8a	5
Swing 250 EC	25a	47.5a	42.5b	792a	0.9ab	31.5	33.2cd	10.1	5a	7.8bc	6.3cd	1
Artea 330 EC	32.5a	15.0b	22.5cd	210c	1.4a	55.8	37.6a	20.6	11.2a	13.8a	15.0bc	2
Silvacur 375 EC	27.5a	12.5b	15.0de	290c	1.2ab	47.9	36.7ab	18.6	6.3a	2.0bc	7.5cd	1
Folicur 250 EC	17.5a	8.8b	11.3e	154c	1.0ab	37.1	36.4abc	18	12.5a	1.0c	6.3cd	1
Stratego 250 EC	22.5a	21.3b	32.5bc	381bc	1.4a	57.3	36.6abc	18.5	6.3a	5.5 abc	8.8cd	1
Soprano 50 EC*	31.25a	40.0a	62.5a	815a	0.8ab	26.5	33.2bcd	10.2	12.5a	10.3ab	12.5bc	2
Orius 5 EW*	20a	10.0b	11.3e	189c	1.2ab	49.6	37.0a	19.2	11.3a	2.0bc	8.8cd	1
Cotaf 5 E*	20a	10.0b	16.3de	225c	1.3ab	51.6	35.9abc	16.7	7.5a	12.5a	18.8ab	2
AmistarXtra 280 SC	17.5a	10.0b	12.5de	210c	1.4a	55.1	36.9a	19.3	7.8a	1.0c	4.0d	1
Mean[h]	23.8	19.5	25.2	363	1.2	45.8	35.9	16.8	8.9	6.2	9.8	
LSD (0.05)	-	1.6	1.1	32.3	0.6	-	3.6	-	-	1.5	1.2	

[u] Treatment means within columns followed by the same letter are not significantly different at P≤0.05 according to least sig
– = no data.

[v] MRS = mean rust severity (modified Cobb scale); 1st, 2nd, and 3rd disease notes were recorded at growth stages 55, 65, and

[w] Yield gain (G) (%) = (fungicide-treated – untreated) × 100/treated.

[x] TKW = 1,000-kernel weight; gain (G) (%) = (fungicide-treated – untreated) × 100/treated.

[y] Active components of the fungicides are as follows: Swing 250 EC, epoxiconazole + carbendazim; Artea 330 EC, cyproconaz
at 250 g/liter; Silvacur 375 EC, tebuconazole + tridimenol; Folicur, tebuconazole; Stratego 250 EC, trifloxystrobin + propicona
EC, epoxiconazole at 125 g/liter + carbendazim at 125 g/liter); Orius 25 EW, tebuconazole; Cotaf 5 E, hexaconazole; and Ami
at 200 g/liter + cyproconazole at 80 g/liter. Soprano 250 EC, Orius 25 EW, and Cotaf 5 E are generic chemicals.

[z] Area under the disease progress curve (AUDPC) values are means of four replications.

IntechOpen

www.intechopen.com

Table 5. Effect of fungicide treatment on stem rust severity, area under the disease progress curve (AUDPC), grain yield, and 1,000-kernel weight on wheat cv.Duma at Eldoret [U]

	2005											
	MRS[V]				Grain yield[W]		TKW[X]		MRS[v]			
Treatment [y]	1st	2nd	3rd	AUDCP[Z]	t/ha	G (%)	Wt. (g)	G (%)	1st	2nd	3rd	
Untreated	12.5a	30.0a	30.0a	643a	0.7c	-	25.0d	-	12.5a	14.0ab	45.0a	
Swing 250 EC	5a	5.0cd	5.0bc	195a	2.1b	67	37.3ab	32.8	13.8a	5.3bc	18.8cd	
Artea 330 EC	7.5a	20.0cd	5.5bc	425a	1.8b	62	35.9 bc	30.3	7.5a	4.3bc	13.8cd	
Silvacur 375 EC	7.5a	7.5bcd	5.5bc	235a	2.1b	66.4	36.1bc	30.7	6.8a	5.3bc	12.5cd	
Folicur 250 EC	7.5a	3.0cd	7.5bc	195a	2.3b	69.4	35.8bc	30.1	13.8a	6.5bc	11.3cd	
Stratego 250 EC	10a	5.0cd	10.0b	257a	1.5b	54.6	33.0c	24.1	13.8a	5.5bc	25.0cd	
Soprano C 250 EC*	7.5a	12.5bc	12.5b	580a	1.6b	55.1	33.7bc	25.8	6.3a	2.0c	7.5d	
Orius 5 EW*	5a	2.5d	5.0bc	172a	2.2ab	68.5	34.1bc	26.6	6.3a	6.3bc	25.0bc	
Cotaf 5 E*	7.5a	7.5cd	5.5bc	221a	2.2ab	67.4	35.1bc	28.6	7.5a	21.3a	37.5ab	
AmistarXtra 280 SC	10a	3.0cd	3.0c	156a	3.0a	76.3	40.1a	37.5	7.5a	3.3c	11.3cd	
Mean[h]	8	7.3	6.6	271	2.1	65.2	35.7	29.6	9.2	6.6	18.1	
LSD (0.05)	1.6	1.6	1.3	571	0.8	-	3.6	-	NS	1.5	1.8	

[u] Treatment means within columns followed by the same letter are not significantly different at P ≤ 0.05 according to least significant difference (LSD) test;

– = no data.

[v] MRS = mean rust severity (modified Cobb scale); 1st, 2nd, and 3rd disease notes were recorded at growth stages 55, 65, an

[w] Yield gain (G) (%) = (fungicide-treated – untreated) × 100/treated.

[x] TKW = 1,000-kernel weight; gain (G) (%) = (fungicide-treated – untreated) × 100/treated.

[y] Active components of the fungicides are as follows: Swing 250 EC, epoxiconazole + carbendazim; Artea 330 EC, cyprocon at 250 g/liter; Silvacur 375 EC, tebuconazole + tridimenol; Folicur, tebuconazole; Stratego 250 EC, trifloxystrobin + propicon EC, epoxiconazole at 125 g/liter + carbendazim at 125 g/liter); Orius 25 EW, tebuconazole; Cotaf 5 E, hexaconazole; and Ar at 200 g/liter + cyproconazole at 80 g/liter. Soprano C 250 EC, Orius 25 EW, and Cotaf 5 E are generic chemicals.

[z] Area under the disease progress curve (AUDPC) values are means of four replications.

IntechOpen

www.intechopen.com

Table 6. Effect of fungicide treatment on stem rust severity, area under the disease progress curve (AUDPC), grain yield, and 1,000-kernel weight on wheat cv. Duma at Mau-Narok [U]

	2005											
	MRS[V]				Grain yield[W]		TKW[X]		MRS[v]			
Treatment [y]	1st	2nd	3rd	AUDCP[Z]	t/ha	G (%)	Wt. (g)	G (%)	1st	2nd	3r	
Untreated	9.0ab	11.5a	35.0a	367.3a	1.3c	-	38.2 b	-	5a	35.0a	40.	
Swing 250 EC	10.0ab	10.0a	13.8b	316.5a	3.0ab	54.8	46.6a	18	1a	12.5bcd	11.	
Artea 330 EC	10.0ab	117.5	9.0b	392.0a	3.4a	60.5	44.0a	13	4a	32.5a	32.5	
Silvacur 375 EC	10.0ab	8.0a	6.5b	236.8a	3.3a	59.8	43.7a	12.6	0.8a	16.3abcd	18.8	
Folicur2 50 EC	13.8a	12.5a	9.0b	347.5a	3.2ab	57.9	45.1a	15.3	0.8a	5.3d	11.	
Stratego 250 EC	13.8a	13.8a	8.0b	358.8a	3.3a	59.7	45.6a	16.1	1a	23.8ab	32.5	
Soprano C 250 EC*	6.3b	12.5a	16.5b	344.0a	3.1ab	56.6	44.1a	13.4	0.5a	15.0bcd	21.3	
Orius 5 EW*	10.0ab	10.0a	3.0b	241.0a	3.1 ab	56.3	44.4 a	14	0.8a	13.8 bcd	13.	
Cotaf 5 E*	6.3b	11.3a	7.8b	264.5a	3.1 ab	56.5	44.3 a	13.7	1a	21.3 abc	30 a	
AmistarXtra 280 SC	6.3b	10.0a	5.5b	230.8a	3.2ab	37.9	44.2a	13.5	1a	8.8cd	13.	
Mean[h]	9.5	11.9	11.4	309.9	3	55.6	44.7	14.4	1.2	16.6	20	
LSD (0.05)	1.0	1.7	1.9	7.2	1	-	3.2	-	NS	1.8	1.	

[u] Treatment means within columns followed by the same letter are not significantly different at P ≤ 0.05 according to least significant difference (LSD) test;

– = no data.

[v] MRS = mean rust severity (modified Cobb scale); 1st, 2nd, and 3rd disease notes were recorded at growth stages 55, 65

[w] Yield gain (G) (%) = (fungicide-treated – untreated) × 100/treated.

[x] TKW = 1,000-kernel weight; gain (G) (%) = (fungicide-treated – untreated) × 100/treated.

[y] Active components of fungicides are as follows: Swing 250 EC, epoxiconazole + carbendazim; Artea 330 EC, cyprocona propiconazole at 250 g/liter; Silvacur 375 EC, tebuconazole + tridimenol; Folicur, tebuconazole; Stratego 250 EC, triflox Soprano C 250 EC, epoxiconazole at 125 g/liter + carbendazim at 125 g/liter; Orius 25 EW, tebuconazole; Cotaf 5 E, he and AmistarXtra 280 SC, azoxystrobin at 200 g/liter + cyproconazole at 80 g/liter; Soprano C 250 EC, Orius 25 EW, an

[z] Area under the disease progress curve (AUDPC) values are means of four replications.

the pattern of stem rust suppression by fungicide treatments was observed at all locations for the 2 years. The lowest mean disease severity after the second treatment were obtained in plots sprayed with AmistaXtra 280 SC followed by Folicur 250 EC, Orius 25 EW and Silvacur 375 EC.

3.3 Effect of fungicides on grain yield

In 2005, fungicide treatments with reduced stem rust severity yielded significantly ($P \leq 0.05$) more grain at Eldoret and Mau-Narok (Table 5 and 6) whereas only Artea 330 EC, Stratego 250 EC and AmistarXtra 280 SC significantly *(*$P \leq 0.05$) increased grain yield at KARI-Njoro (Table 5). Similarly, in 2006, treatments that had reduced stem rust severity significantly ($P \leq 0.05$) increased grain yield, except for Cotaf 5 E at KARI-Njoro and Eldoret; and Swing 250 EC and Soprano C 250 EC at the latter site. The mean grain yield among the treatments ranged from 1.3 to 2.6 t/ha. Highest yield, 2.6 t/ha, was obtained in plots of AmistarXtra 280 SC, which was 50% higher than the untreated control.

3.4 Effect of fungicides on kernel weight

All fungicide treatments that had significantly ($P \leq 0.05$) higher grain yield also had higher 1,000-kernel weight. In 2005, 1,000-kernel weights from treated plots at all locations were significantly ($P \leq 0.05$) higher than those from untreated control plots. The trend for both grain yield and 1,000-kernel weight in 2006 was similar, except at Eldoret and Mau-Narok (Table 4, 5, and 6).

3.5 Effect of Nativo 300 SC and Prosaro 250 EC on stem rust severity

All the foliar fungicide treatments reduced stem rust on wheat cultivar 'Duma'(data not shown). Fungicide applications significantly ($P \leq 0.05$) reduced mean rust severity (MRS) compared to the untreated control, with Prosaro 250 EC at 1.0 L/ha, Nativo at 0.75 L and 1.0 L/ha and the standards (Folicur 250 EC and AmistarXtra 280 SC), performing better than Prosaro 250 EC at 0.6 L/ha, 0.75 L/ha and Nativo 300 SC at the rate of 0.6 L/ha. The highest disease severity reduction in 2006 was generally observed in plots that were sprayed with Prosaro 250 EC at 1.0 L/ha (59.4%), Nativo 300 SC and AmistaXtra 280 SC at 1.0 L/ha (55.6% each) at KARI-Njoro and Prosaro 250 EC at 0.6 L/ha (75.7%), Prosaro 250 EC at 1.0 L/ha (75.5%) and Nativo 300 SC at 1.0 L/ha (73.5%) at Mau-Narok. In 2007, the highest disease severity reduction was in plots sprayed with Folicur 250 EC at 1.0 L/ha (85.3%), followed by Prosaro 250 EC at 0.75 L/ha (82.6%) and 1.0 L/ha (77.8%) at KARI-Njoro and Prosaro 250 EC at 0.6 L/ha (76.5%), Prosaro 250 EC at 1.0 L/ha (75.5%), and Nativo 300 SC at 1.0 L/ha (73.47%) at Mau-Narok .

The average grain yields and 1,000-kernel weights across the locations varied from one treatment to another, ranging from 1.2 - 4.0 t/ha and 28.5 - 45.4 g, respectively. Significant ($P \leq 0.05$) grain yield increases of 57.3% and 49.7% were obtained at KARI-Njoro and Mau-Narok in 2006, while 54.1% and 44.7% increases occurred in 2007, respectively. Similar increases in 1,000-kernel weight occurred at both sites; KARI-Njoro (24.5% and 25.1%) in 2006, and 10.4% and 23.3% in 2007.

4. Discussion

There is very little information published on the use of fungicide to control wheat stem rust, specifically related to the race TTKSK (Ug99) that is prevalent in the Eastern Africa region.

The occurrence of stem rust and the onset of epidemics differed from year to year and location to location. In this study, three locations, KARI-Njoro, Eldoret, and Mau-Narok, were selected because of their stem rust favourable weather conditions. Generally, these areas have hot days of 23°-30°C, mild night temperatures below 15°C and adequate moisture for night dews. Under such favourable conditions, the growth and spread of the stem rust pathogen can greatly reduce grain yield and 1,000-kernel weight in susceptible cultivars. Stem rust epidemics were high in 2005 and 2006 at KARI-Njoro. The rust development began early due to the warm and moist environmental conditions that prevailed. At Eldoret, rust severity was moderate in 2005 but high in 2006. Even though the Mau-Narok location experienced cooler weather and frequent rainfall during the growth seasons, rust severity was moderate before application of fungicides.

Stem rust caused 32 to 57% of grain yield loss and 17 and 24% of 1,000- kernel weight reduction in the experiments at the three locations in 2005 and 2006, respectively. These results were consistent with losses reported in other studies (Dill-Mackey et al., 1990; Loughman et al., 2005, and Paveley et al., 2003).

Yield losses of 50% due to stem rust infection have been reported in a recent study (Expert Panel , 2005). Previously, Pretorius (1983) had reported that yield losses caused by stem rust ranged from 7 to 35% depending on cultivar. Dill-Mackey et al. (2000) induced severe stem rust epidemics in barley and wheat and observed yield losses of 50 to 58%. Mayfield (1985) found a clear relationship between grain yield and disease severity by demonstrating that prevention of a 1% increase in rust severity saved a 2% loss in grain yield. Different fungicides vary in their efficacy to control stem rust. Loughman et al., 2005 reported that Folicur (tebuconazole) was more effective than Triad (triadimefon) or Impact (flutriafol) in disease reduction and yield increase. In the present study, all fungicide applications resulted in lower disease severity and higher yields than untreated check plots. However, AmistarXtra 280 SC, Folicur 250 EC, Silvarcur 375 EC and Orius 25 EW were more effective than other treatments in reducing disease and increasing yield. The effectiveness of Stratego 250 EC, Cotaf 5 E, Swing 250 EC, Artea 330 EC, and Soprano C 250 EC was inconsistent. Therefore, growers should choose fungicides based on their efficacy.

Stem rust severity was relatively low in 2005 at Eldoret and Mau-Narok than in KARI- Njoro but treatments significantly increased grain yield. The yield increase by fungicide applications under low disease pressure could be due, in part, to phytonic effect of fungicides. This stimulatory effect of fungicide treatments on growth may result in significant yield increases even in the absence of the disease (Wegulo et al., 1998). Fungicide treatments, if applied under high and moderate disease pressure at critical growth stages may reduce large yield losses by suppressing or eliminating stem rust pathogen (Mayfield, 1985). However, greater rust control and greater yield increases may have been possible using higher rates and more applications of fungicides as well as spraying at an earlier stage of the rust epidemic. Under field conditions, a stem rust severity level greater than 5% in 'hot- spot' regions should be controlled to reduce yield losses (Loughman et al., 2005). For this study, there was a sudden explosion of the disease within a few days due to ideal climatic conditions, which contributed to the high stem rust severities recorded at the KARI-Njoro location before the first fungicide application. This provided ideal conditions for assessing efficacies of the fungicides.

For Nativo 300 SC and Prosaro 250 EC, stem rust severity was relatively low in 2007 in the trials at KARI-Njoro and Mau-Narok compared to 2006, but there was grain yield increase in response to fungicide applications. A similar yield increase under relatively low disease

pressure was recorded during the assessment of commercial foliar fungicides. Therefore, the two new fungicides were recommended for commercial use in the control of stem rust in Kenya.

The impact of fungicide application in the management of stem rust was well illustrated at the three locations. Significant differences were found among fungicides in their ability to suppress disease development and protect crop canopy, which is vital for dry matter accumulation and yield (Viljanen-Rollinson et al., 2006). The efficacy differences among the tested fungicides were probably related to their fungicidal activity. The two studies demonstrated that fungicide treatments applied under high and moderate disease pressure at critical crop growth stages increase grain yield of susceptible varieties by suppressing or eliminating the negative effects of the rust. The adoption of effective foliar fungicides to combat stem rust pathogen as a short term control strategy until resistant varieties are developed should be encouraged. However, more research is required to identify the precise timing of fungicide sprays and doses.

5. The future

The demand for new innovative chemicals will continue to be strong, but these alone will not be the answer to reduced crop losses. On-going studies show that amongst all the management strategies, slow rusting wheat varieties are providing the most effective, long-term and cost effective control over stem rust (Singh et al., 2006). Fungicides can be a valuable tool in increasing yields and profitability of wheat production, especially if disease susceptible varieties are grown and, where the disease pressure is only moderate. But combining fungicides with host resistance offers the best monetary return when disease pressure is high (Ransom et al., 2008). This should be linked to accurate disease forecasting and timely application of chemicals (Sbragia, 1975). While the impetus on breeding high yielding varieties will continue, the emphasis on disease resistance will even be higher. Appropriate management of the few effective resistance genes remaining through deployment and pyramiding will require greater attention to prevent their rapid breakdown.

6. Acknowledgment

The authors thank the agrochemical companies and Borlaug Global Rust Initiative (BGRI) for partial funding of the studies; and our colleagues in the pathology section, specifically D. Onyango and P. Kinyanjui, for their tireless support during the implementation of the experiments.

7. References

Bradley, R. S. (2004). UK rules for growing Wheat: Might Australian crops comply. http://www.grdc.com.au/growers/res_upd/s04/Sylvester.htm (2007/02/22).

Bartlett, D. W., Clough, J. M., Godwin, J. R., Hall, A. A., Hamer, M., and Parr-Dobrzanski, B. (2002). Review: The Strobilurin Fungicides. *Pest Management Sci.* 58: 649-662.

Bertelsen, J. R., de Neergaard, E. and Smedegaard-Petersen, V. (2002). Fungicidal effects of azoxystrobin and epoxiconazole on phylosphere fungi, senescence and yield of winter wheat. *Plant Pathol.* 50: 190-205.

Burgeno, J., Cadena, A. R., Crossa, J., Banzinger, M., Gilmour, A. R. and Cullis, B. R. (2000). User's Guide for Spatial Analysis of Field variety Trials using ASREML, CIMMYT, Mexico. D.F.

Carisse, O., Meloche, C., Boivin, G. and Jobin, T. (2009). Action Thresholds for Summer Fungicide Sprays and Sequential Classification of Apple Scab Incidence. *Plant Dis*. 93 (5): 490-498.

Cook, R. J., Hims, M. J. and Vaughan, (1999). Effects of fungicide spray timing on winter wheat disease control. *Plant Pathology* 48: 33-50.

Dill-Mackey, R., Rees, R. G. and Platz, G. J. (1990). Stem rust epidemics and their effects on grain yield and quality in Australian barley cultivars. *Aust. J. Agric. Res*. 41: 1057-1063.

Dill-Macky, R., and Roelfs, A. P. (2000). The effect of stand density on the development of *Puccinia graminis* f. sp. *tritici* in barley. *Plant Dis.* 84: 29-34.

Expert Panel on the Stem Rust Outbreak in East Africa. (2005). Sounding the alarm on global stem rust: An assessment of race Ug99 in Kenya and Ethiopia and potential for impact in neighbouring regions and beyond. CIMMYT, Mexico, D. F. 1-25pp.

Guthrie, E. J. (1966). Investigation into physiologic specialization in wheat stem rust. Information bulletin on the near east wheat and barley improvement project. Vol. III, p. 15-20. FAO Near East Regional Office, Cairo, UAR.

Green, G. J., Martens, J. W., and Ribeiro, O. (1970). Epidemiology and Specialization of Wheat and Oat stem rust in Kenya in 1968. *Phytopathology* 60: 309-314.

Harder, D. E., Mathenge, G. R., and Mwaura, L. K. (1970). Physiologic Specialization and Epidemiology of Wheat Stem Rust in East Africa. *Phytopathology* 62: 166-171.

Jin, Y. and Szabo, L. J., Pretorius, Z. A., Singh, R. P., Ward, R., and Fetch, T., (2008). Detection of virulence to resistance gene *Sr* 24 within race TTKS of *Puccinia graminis* f. sp. *tritici*. *Plant Dis*. 92: 923-926.

Jin, Y., Singh, R. P., Ward, R. W., Wanyera, R., Kinyua, M., Njau, P., Fetch, T., Pretorius, Z. A., and Yahyaoui, A. (2007). Characterization of Seedling Infection Types and plant Infection Responses of Monogenic *Sr* Gene lines to Race TTKS of *Puccinia graminis* f. sp. *tritici*. *Plant Dis*. 91: 1096-1099.

Knight, S. C., Anthony, V. M., Brady, A. M., Greenland, A. J., Heaney, S. P., Murray, D. C., Powell, K. A., Schulz, M. A., Spinks, C. A., Worthington, P. A. and Youle, D. (1997). Rational and perspectives on the development of fungicides. *Annual Review of Phytopathology* 35: 349-372.

Loughman, R., Jayasena, K., and Majewski, J. (2005). Yield loss and fungicide control of stem rust of wheat. *Aust. J. Agric. Res.* 56: 91-96.

Mayfield, A. H. (1985). Efficacies of fungicides for the control of stem rust of wheat. *Aust. J. Exp. Agric.* 25: 440-443.

McDonald, M. R. (2006). Advances in conventional methods of disease management. *Can. J. Plant Pathol.* 28: S239-S246.

Milne, A., Paveley, N., Audsley, E. and Parsons, D. (2007). A model of the effect of fungicides on disease- induced yield loss, for use in wheat disease management decision support systems. *Annals of Applied Biology* 151: 113-125.

Niks, R. E. and Lindhout, W. H. (2006). Breeding for Resistance against diseases and Pests. Wageningen University Laboratory of Plant Breeding. Pp. 61-63.

Paveley, N. D., Thomas, J. M., Vaughan, T. B., Havis, N. D., and Jones, D. R. (2003). Predicting effective doses for the joint action of two fungicide applications. *Plant Pathol.* 52: 638-647.

Peterson, R. F., Campbell, A. B., and Hannah, A. E. (1948). A diagrammatic scale for estimating rust intensity of leaves and stems of cereals. *Can. J. Res.* 26: 496-500.

Kromann, P., Taipe, A., Perez, W. G., and Forbes, G. A. (2009). Rainfall Thresholds as support for Timing Fungicide Applications in the Control of Potato Late Blight in Ecuador and Peru. *Plant Dis.* 93 (2): 142-148.

Pretorius, Z. A., Singh, R. P., Wagoire, W.W. and Payne, T. S. (2000). Detection of virulence to wheat stem rust gene *Sr*31 in *Puccinia graminis* f. sp. *tritici* in Uganda. *Phytopathology* 84: 203.

Pretorius, Z. A. (1983). Disease Progress and yield response in spring wheat cultivars and lines infected with *Puccinia graminis* f. sp. *tritici. Phytophylactica* 15: 35-45.

Ransom, J.K. and McMullen, M. V. (2008). Yield and Disease Control on Hard Winter wheat Cultivars with Foliar Fungicides. *Agron. J.* 100: 1130-1137.

Reynods, M. P., and Borlaug, N. E. (2006). Applying innovations and new technologies from international collaborative wheat improvement. *Journal of Agricultural Sciences* 144: 95-110.

Rowell, J. B. (1981). Control of stem rust on spring wheat by triadimefon and fenapanil. *Plant Dis.* 65: 235-263.

Sbragia, R. J. (1975). Chemicals control of plant disease: an exciting future. *Annual Review of Phytopathology* 13: 257-263.

Saari, E. E., and Prescott, J. M. (1985). World distribution in relation to economic losses. *In* "The Cereal Rusts Vol. II. Diseases, Distribution, Epidemiology, and Control" (A. P. Roelfs, and W. R. Bushnell, Eds.). pp. 259-98. Academic Press, Orlando.

Singh, R. P., Hodson, D. P., Huerta-Espino, J., Jin, Y. Njau, P., Wanyera, R., Herrera-Foessel, S. A., and Ward, R. W. (2008). Will Stem Rust Destroy the World's Wheat Crop? In "Advances in Agronomy Vol. 98. (Sparks D. L. Eds). pp. 271-309. Elsevier Inc, USA.

Steel, R. G. D., and Torrie, J. H. 1980. Principles and Procedures of statistics. A biometrician Approach. McGraw-Hill Book Company, New York, 2nd Edition. 633pp.

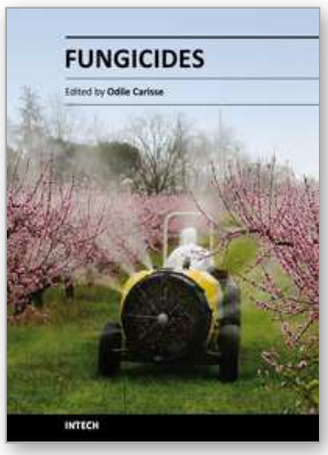
Viljanen-Rollinson, S. L. H., Marroni, M. V., and Butler, R. C. 2006. Wheat Stripe Rust Control using Fungicides in New Zealand. *New Zealand Plant Protection* 59: 155-159.

Wanyera, R., Macharia, J. K., Kilonzo, S. M., and Kamundia, J. W. 2009. Foliar fungicides to control wheat stem rust, race TTKS (Ug99), in Kenya. *Plant Dis.*93: 929-932.

Wanyera, R., Kinyua, M.G., Jin. Y., and Singh, R.P. 2006. The spread of the stem rust caused by *Puccinia graminis* f. sp. *tritici*, with virulence on *Sr31* in wheat in Eastern Africa. *Plant Dis.* 90: 113.

Wegulo, S. N., Rivera-C, J. M., Martison, C. A., and Nutter, F. W., Jr. 1998. Efficacy of fungicide treatments for common rust and northern leaf sport in hybrid corn seed production. *Plant Dis.* 82: 547-554.

Zadoks, J. C., Chang, T. T., and Konazak, C. F. 1974. A decimal code for growth stages of cereals. *Weed Res.* 14: 415-421.



Fungicides

Edited by Odile Carisse

ISBN 978-953-307-266-1

Hard cover, 538 pages

Publisher InTech

Published online 14, December, 2010

Published in print edition December, 2010

Plant and plant products are affected by a large number of plant pathogens among which fungal pathogens. These diseases play a major role in the current deficit of food supply worldwide. Various control strategies were developed to reduce the negative effects of diseases on food, fiber, and forest crops products. For the past fifty years fungicides have played a major role in the increased productivity of several crops in most parts of the world. Although fungicide treatments are a key component of disease management, the emergence of resistance, their introduction into the environment and their toxic effect on human, animal, non-target microorganisms and beneficial organisms has become an important factor in limiting the durability of fungicide effectiveness and usefulness. This book contains 25 chapters on various aspects of fungicide science from efficacy to resistance, toxicology and development of new fungicides that provides a comprehensive and authoritative account for the role of fungicides in modern agriculture.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Ruth Wanyera, Joseph Kinyoro Macharia and Samuel Kilonzo (2010). Challenges of Fungicide Control on Wheat Rusts in Kenya, Fungicides, Odile Carisse (Ed.), ISBN: 978-953-307-266-1, InTech, Available from: http://www.intechopen.com/books/fungicides/challenges-of-fungicide-control-on-wheat-rusts-in-kenya

INTECH
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2010 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike-3.0 License, which permits use, distribution and reproduction for non-commercial purposes, provided the original is properly cited and derivative works building on this content are distributed under the same license.

IntechOpen

IntechOpen