2.5 Preventative action

The Durable Rust Resistance in Wheat Project, a collaborative effort begun in April 2008, which now includes 22 research institutions around the world and led by Cornell University, seeks to mitigate rust threats through coordinated activities that will replace susceptible varieties with durably resistant varieties, created by accelerated multilateral plant breeding and delivered through optimized developing country seed sectors. The project also aims to harness recent advances in genomics to introduce non-host resistance (immunity) into wheat.

Improved international collaboration in wheat research to meet growing world demand for food—an estimated 50% production increase in wheat alone is needed by 2020—is another major goal of this project. For more information about how to get involved with this project, please contact the DRRW coordination office.

Reports

- DRRW Annual Report 2013
- Project Impacts 2013

Prevention is essential for effective integrated management

For effective integrated management of wheat rust diseases close monitoring, international collaboration and strengthening of national capacities are crucial. Although in certain cases fungicide application may be necessary, it may not be practical or economical in all countries especially in the developing world where wheat is a subsistence crop for small holder farmers. Thus preventive approaches are the most effective and environmentally friendly means of wheat rust management, use of resistant cultivars being the most effective tool. Thus, emphasis must be given to breeding resistant varieties and seed multiplication with the aim of making these seeds available to farmers as quickly as possible. However this process is slow in most cases and it should be improved through better coordination among the stakeholders and contingency planning.

To achieve sustained and improved productivity in wheat, increased investments are needed to support regional and international collaboration initiatives as well as capacity development efforts for effective implementation of integrated disease management practices at national level. Emphasis should be given to promotion of preventive approaches such as deployment of resistant cultivars, rapid seed multiplication systems, rapid surveillance approaches, institutional coordination and contingency planning for effective emergency response capability. Efforts should be intensified especially to strengthen national capacities in the regions which are at risk of wheat rust epidemics particularly in East and North Africa, Near East and Central and South Asia.

Wheat Rust Diseases Global Programme

FAO has been running a global programme on wheat rust diseases since 2008 to provide policy and technical support to the concerned countries, in the context of the Borlaug Global Rust Initiative (BGRI). Emphasis is placed on prevention, by promoting the development and planting of resistant cultivars, use of certified seeds, rapid seed multiplication, training of farmers, strengthening surveillance and emergency response capacities, promoting research – extension – farmer linkages and international cooperation.

FAO has developed its programme focusing on following components to plan its activities in response to the global wheat rust threat. It emphasizes regional and international cooperation and information sharing, tackling both the immediate needs of farmers and long-term needs of the agriculture sector:

- **Coordination and planning**
  FAO ensures all national stakeholders are involved in prevention and preparedness
- **Surveillance and early warning**
  FAO works with countries to improve capacities to undertake disease surveys and exchange information with the Global Rust Monitoring System
- **Variety Registration**
  FAO supports national testing and quick release of new resistant varieties in directly affected countries
- **Seed Systems**
  FAO establishes methods to ensure quick multiplication and distribution of resistant variety seeds in countries affected or at risk
- **Integrated disease management at field level**
  FAO works closely with research and extension institutions and farmers to protect wheat crops and increase yields under local farming conditions
- **International and regional collaboration**
  FAO contributes to and promotes international and regional cooperation in collaboration with the partners

Partnerships
Projects and activities of the programme are implemented through collaboration with national governments and their institutions, regional bodies, research and development institutions, the donor community and rural communities bringing together excellent complementarities.

The major international partners include the following:

- BGRI (Borlaug Global Rust Initiative)
- ICARDA (International center for Agricultural Research in Dry Areas)
- CIMMYT (International Wheat and Maize Improvement Center)
- Cornell University (USA),
- AARHUS University (Denmark)
- IFAD (International Fund for Agricultural Development),

Management of rust fungi diseases

The control methods of rust fungus diseases depend largely on the life cycle of the particular pathogen. The following are examples of disease management plans used to control macrocyclic and demicyclic diseases:-

Macrocyclic Disease: Developing a management plan for this type of disease depends largely on whether the repeating stage (urediniospores) occur on the economically important host plant or the alternate host. For example, the repeating stage in **white pine blister rust disease** does not occur on white pines but on the alternate host, *Ribes spp.* During August and

September *Ribes spp.* give rise to teliospores which infect white pines. Removal of the alternate host disrupts the life cycle of the rust fungi *Cronartium ribicola*, preventing the formation of basidiospores which infect the primary host. Although spores from white pines cannot infect other white pines, survival spores may overwinter on infected pines and reinfect *Ribes spp.* the following season. Infected tissue is removed from white pines and strict quarantines of *Ribes spp.* are maintained in high risk areas.[18][19]

Puccinia graminis is a macrocyclic heteroecious fungus that causes wheat stem rust disease. The repeating stage in this fungus occurs on wheat and not the alternate host, barberry. The repeating stage allows the disease to persist in wheat even though the alternate host may be removed. Planting resistant crops is the ideal form of disease prevention, however, mutations can give rise to new strains of fungi that can overcome plant resistance. Although the disease cannot be stopped by removal of the alternate host, the life cycle is disrupted and the rate of mutation is decreased because of reduced genetic recombination. This allows resistance bred crops to remain effective for a longer period of time.[20][21]

Demicyclic Disease: Because there is no repeating stage in the life cycle of demicyclic fungi, removal of the primary or the alternate host will disrupt the disease cycle. This method, however, is not highly effective in managing all demicyclic diseases. Cedar-apple rust disease, for example, can persist despite removal of one of the hosts since spores can be disseminated from long distances. The severity of Cedar-apple rust disease can be managed by removal of basidiospore producing galls from junipers or the application of protective fungicides to junipers.[22]

Home control

Rust is very hard to treat. Fungicides such as Mancozeb or Triforine may help but may never eradicate the disease. Some organic preventative solutions are available and sulphur powder is known to stop germination. High standards of hygene and good soil drainage and careful watering may minimise problems. Any appearance of rust must be immediately dealt with by removing and burning all affected leaves. Composting, or leaving infected vegetation on the ground will spread the disease.

Commercial control

In large plantations in USA, fungicides are applied by air. The process is expensive and fungicide application is best reserved for seasons when foliar diseases are severe. Research indicates, the higher the foliar disease severity, the greater the return from the use of fungicides.[23] There are a variety of preventative methods that can also be employed.

- Symptoms of rust disease are correlated to relatively high moisture. The avoidance of overhead watering at night, using drip irrigation, reducing crop density, and using fans to circulate air flow will lower the relative moisture and decrease the severity of rust infection.
- The use of rust resistant plants
- Crop rotation can break the disease cycle because many rusts are host specific.
- Inspect all imported plants and cuttings for symptoms. It is important to continuously observe these plants because rust diseases have a latent period (plant has the disease but shows no symptoms).
- Many crops, such as wheat, are replanted with disease-free seed.[24][25]

Expansion Control by Genetic Engineering

Even though there are many different types of control out there, it is evident that by far, gene manipulation is the most effective way to combat the stem wheat rust gene strain *Ug99* (Schumann and Leonard., 2000). Recently, 50 strains of resistant genes have already been cataloged, although not all of them work with all the different strains that *Ug99* displays (Singh et al., 2011). Only a few genes have been found effective against most of *Ug99* variations, including *Sr22*, *Sr26*, *Sr35*, and *Sr50* (2011).

Some of these genes have already been successful in the past, like the *Sr26* gene which has already been used in the 1970s, 1980s, and it is even being used up to this day (Singh et al., 2011). One of the most important facts about this certain gene strain is that it has remained effective even after it has been used in such large scales. Resistant gene strains tend to lose their potency once they are widely used in a large scale, so *Sr26*'s continuous effectiveness can give us a cause for hope. The only problem is that this gene has only been used in Australia, so the effect that it would have on other parts of the globe is still unknown. *Sr50*, which was introduced to wheat from Imperial rye, has also been deployed in Australia, but no varieties have been released (2011).

Country released	Variety name	CIMMYT name or cross	Stem rust reaction[a]	Ug99 resistance
Afghanistan	Koshan 09	Quaiu #1	40 MR	*Sr2*, *SrTmp*
Afghanistan	Muqawim 09	Oasis/SKauz//4*Bcn/3/2*Pastor	10 R	*Sr2*, *Sr25*
Afghanistan	Baghlan 09	Picaflor#1	5 MS	APR[b] (*Sr2*+)
Afghanistan		Chonte#1	5 MS	APR (*Sr2*+)
Bangladesh		Frankolin#1	10 MS-S	APR (*Sr2*+)
Egypt	Misr 1	Oasis/SKauz//4*Bcn/3/2*Pastor	10 R	*Sr2*, *Sr25*
Egypt	Misr 2	Skauz/Bav92	10 R	*Sr2*, *Sr25*
Ethiopia	Danda	Danphe#1	1 MS	APR (*Sr2*+)
Ethiopia	Kakaba	Picaflor#1	5 MS	APR (*Sr2*+)
India	Super 152	Pfau/Seri.1B//Amad/3/Waxwing	30 MS-S	APR (*Sr2*+)
India	Super 172	Munal#1	15 MS-S	APR (*Sr2*+)
India	Baz	Waxwing/4/Sni/Trap#1/3/Kauz*2/Trap//Kauz	10 MR-MS	APR (*Sr2*+)
India	Ufan	Frankolin#1	10 MS-S	APR (*Sr2*+)
Kenya	Robin	Babax/Lr42//Babax*2/3/Tukuru	15 R-MR	*Sr2*, *SrTmp*
Kenya	Eagle 10	Emb16/Cbrd//Cbrd	10 R-MR	*SrCbrd*
Nepal		Frankolin#1	10 MS-S	APR (*Sr2*+)
Nepal		Picaflor#1	1 MS	APR (*Sr2*+)
Nepal		Danphe#1	1 MS	APR (*Sr2*+)
Pakistan	NR356	Oasis/SKauz//4*Bcn/3/2*Pastor	10 R	*Sr2*, *Sr25*

[a]Ug99 reaction recorded when susceptible check Cacuke became necrotic approximately one week after displaying 100 S reaction; it has two components, percent disease severity based on the modified Cobb Scale (34) and host response as described by Roelfs et al. (39). Abbreviatons: R, resistant (small uredinia surrounded by necrosis or chlorosis); MR, medium-sized uredinia surrounded by necrosis or chlorosis; MS, medium-sized uredinia without chlorosis or necrosis; S, large-sized uredinia without chlorosis or necrosis.
[b]Adult plant resistance based on the *Sr2* complex.

Figure 7: Variations of *Ug99*-resistant wheat that were released in eight countries in 2010. The level of resistance that they had to the fungus was also recorded.
http://www.annualreviews.org/doi/pdf/10.1146/annurev-phyto-072910-095423

Some of these genes initially seemed highly effective against *Ug99*, such as gene and *Sr35*. This gene, after being cultured tested in Australia, was found to be virulent to many of the other races of stem wheat rust throughout the world (Singh et al., 2011). Avirulence to gene *Sr28* by *Ug99* was found, but that same gene has also been found to be virulent to many other races of stem rust throughout the world (2011). The virulence and avirulence on these genes suggest that although some genes might be effective against certain races of stem rust, they might be ineffective against others. These findings should remind us that careful planning should be made when deciding which and where different resistant strains should be planted.

The combination of different resistance genes in a wheat plant can also give synergistic effects. There is evidence that genes that on their own only have moderate resistance to *Ug99* actually have high levels of resistance when paired with another one. This is certainly the case with gene *SrCad* and *Lr34*. *SrCad* gives moderate resistance to *Ug99* while *Lr34,* a leaf wheat rust resistance gene, slows the rusting of the leaves (Singh et al., 2011).

There are also genes that display resistance to the *Ug99* strain but are linked to undesirable traits in the wheat plant (Signh et al., 2011). This could to be true for gene *Sr2*, which has been known to display slow rusting resistance. The problem with this gene is that it has been the general belief that this certain gene is linked to pseudo black chaff expression. Pseudo black chaff expression is often seen as a marker for disease and physiological disorders. But studies have shown that this detrimental linkage can be broken (Mishra et al., 2005), as well as this gene is starting to be used to create *Ug99* resistant wheat crops (Signh et al., 2011).

There are many different things that have been done in order to reduce the *Ug99* risk. One of them is the promotion of *Ug99* resistant varieties in the farmer's wheat fields since they are not able to afford chemicals to apply to their crops if an epidemic hits (Singh et al., 2011). There has also been continuous testing of high-yielding resistant wheat from international centers in order to try and increase the resistance variety of already existing high yielding wheat (2011).

In order to increase the *Ug99* resistant varieties in the farmer's wheat fields, there have been screenings of wheat from countries that have already been affected by the *Ug99* strain. The screenings of plants materials from up to 22 countries have been taking place in Kenya and Ethiopia since 2005 (Signh et al., 2011). This program has been successful since a variety of gene resistant crops have been deployed in eight different countries including Egypt, Afghanistan, and India to name a few (Figure 7). These efforts have been done through the collaboration of many different programs, farmers, and private organizations.

The wheat crops that are most widely grown in the countries affected by *Ug99* are around 10 to 15 years old (Signh et al., 2011). More productive resistant genes have started to be released in different countries (2011). The older strains of wheat should be replaced with resistant strain wheat as soon as possible in order to minimize the area that contains non-resistant wheat strains before an epidemic hits.

Other Types of Control

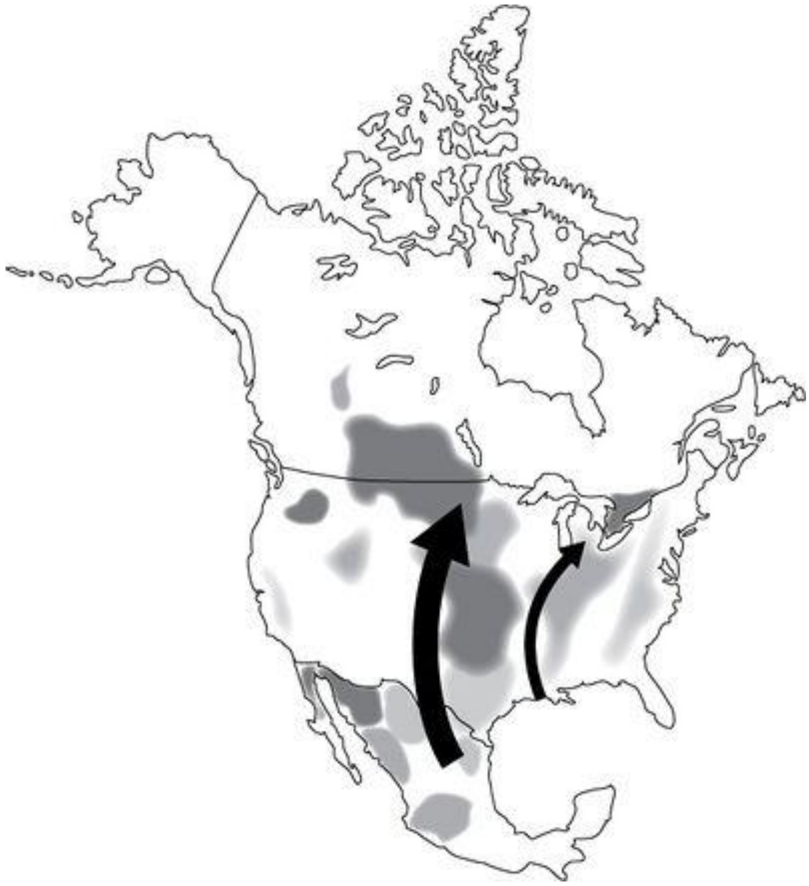

Figure 8: The "Puccina pathway," which is the movement of urediniospores north by the wind from southern North America and Mexico.
http://www.apsnet.org/edcenter/intropp/lessons/fungi/Basidiomycetes/Pages/StemRust.aspx

After it was known that the barberry plants were needed for *Puccinia graminis* to complete its life cycle, North America launched a barberry survey and eradication program in 1918 and still continues of the this day (Schumann and Leonard, 2000). It was believed that by getting rid of the barberry, the stem rust would not have a host to infect once the wheat season was over. Since the stem rust would not have a host, the urediniospores would not be able to survive the winter, ultimately getting rid of stem rust (2000).

Even though North America was not able to get rid of the problem due to the “Puccina pathway, (Figure 8)” which is the movement of urediniospores from southern U.S. and Mexico northward following wind currents, it did have some positive effects on the control of the epidemic (Schumann and Leonard, 2000). One of the positive effects is that it removed a huge source of spore production, since a single plant can produce billions of aeciospores (2000). By getting rid of one of the biggest sources of pollen, the dispersal of stem rust has slowed down dramatically (2000). The program also got rid of the sexual cycle of P. graminis, which dramatically reduced the amount of new strains that the fungi usually produced. This is due to the fact that the fungi can now only mostly reproduce asexually. One of the biggest successes of this program is that it decreased the amount of races of wheat stem rust since now its primary source of genetic variation is the slower process of mutation (2000).

The Global Wheat Rust Monitoring System (RustTracker) reports about a potential outbreak of yellow rust epidemics in CWANA.

2013.05.22 | JENS GRØNBECH HANSEN

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The Global Wheat Rust Monitoring System (RustTracker) reports about a potential outbreak of yellow rust epidemics in CWANA. GRRC was informed by colleagues from CIMMYT and ICARDA about the emerging risks at an early stage in spring 2013. By May 20, GRRC has issued permits for the submission of rust infected wheat samples from Afghanistan, Azerbaijan, Bhutan, Egypt, Iraq, Iran, Lebanon, Morocco and Uzbekistan. So far, samples have been recovered from Afghanistan, Bhutan, Iraq, and Morocco.

The main purpose of this activity is to characterize recovered rust isolates for virulence phenotype on resistant wheat plants in order to detect potential shifts in pathogen virulence, which may put new wheat varieties at risk. Selected isolates will also be subject to DNA fingerprinting in order to detect the genetic relatedness among isolates from different epidemic sites and to resolve possible mechanisms of evolution. Isolates with interesting new features are stored at GRRC to assist future resistance breeding efforts and research. First results of the virulence phenotyping are expected by the end of June and will be posted on this website, RustTracker and related websites of collaborators.

Wheat Sr genes

A number of stem rust resistance genes (Sr genes) have been identified in wheat.[6] Some of them arose in bread wheat (e.g. *Sr5* and *Sr6*), while others have been bred in from other wheat species (e.g. *Sr21* from *T. monococcum*) or from other members of the tribe *Triticeae* (e.g. *Sr31* from rye and *Sr44* from *Thinopyrum intermedium*).

None of the Sr genes provide resistance to all races of stem rust. For instance many of them are ineffective against the *Ug99* lineage.[6] Notably *Ug99* has virulence against *Sr31*, which was effective against all previous stem rust races.

Singh et al., [2011] provide a list of known Sr genes and their effectiveness against *Ug99*.[6]

Host Resistance

Plant breeders have tried to improve yield quantities in crop like wheat from the earliest times. In recent years, breeding for the resistance against disease proved to be as important for total wheat production as breeding for increase in yield. The use of single resistance gene against various pests and diseases plays a major role in resistance breeding for cultivated crops. The earliest single resistance gene was identified effective against yellow rust. Numerous single genes for leaf rust resistance have since been identified, the 47th genes prevent crop losses due to *Puccinia recondite* Rob. Ex Desm. f.sp. *tritici* infections, which can range from 5-15% depending on the stage of crop development.

Leaf rust resistance gene is an effective adult-plant resistance gene that increases resistance of plant against *P. recondita* f.sp. *tritici* (UVPrt2 or UVPrt13) infections, especially when combined with genes Lr13 and gene Lr34 (Kloppers & Pretorius, 1997). Lr37 originates from the French cultivar VPM1 (Dyck & Lukow, 1988). The line RL6081, developed in Canada for Lr37 resistance, showed seedling and adult-plant resistance to Leaf, yellow and stem rust. Crosses between the French cultivars will therefore introduce this gene into local germplasm. Not only will the gene be introduced, but the genetic variation of South African cultivars will also increase

Molecular techniques have been used to estimate genetic distances among different wheat cultivars. With the genetic distances known predictions can be made for the best combinations concerning the two foreign genotypes carrying gene Lr37, VPMI and RL6081 and local South African cultivars. This is especially important in wheat with its low genetic variation. The gene will also be transferred with the least amount of backcrosses to cultivars genetically closest to each other, generation similar genetic offspring to the recurrent parent, but with gene Lr37, Genetic distances between near isogenic lines (NILs) for a particular gene will also give an indication of how many loci, amplified with molecular techniques, need to be compared in order to locate putative markers linked to the gene.

Control (leaf)

Varietal resistance is important. Chemical control with triazole fungicides may be useful for control of infections up to ear emergence but is difficult to justify economically in attacks after this stage.

2.5.6 Australia

Economic importance

Rusts are the most important foliar diseases of wheat in Australia. Compared to stripe and stem rust, leaf rust is potentially the least damaging in susceptible varieties, but in most seasons conditions are conducive for this disease. In most parts of Victoria leaf rust is effectively controlled with resistant varieties, but it can cause problems in areas where susceptible varieties are grown.

In Victoria, severe leaf rust infections can reduce grain yield by more than 20 per cent in susceptible varieties, and can also reduce grain quality. In recent years losses from leaf rust have been confined to districts where susceptible varieties were grown.

Disease cycles

The most important host for rusts are susceptible volunteer wheat plants growing during the summer/autumn. Rust cannot carry over from one season to the next on seed, stubble or in soil. Leaf rust is caused by the fungus Puccinia triticina. Leaf rust, like other Wheat varieties susceptible to leaf rust enable inoculum levels to build up on volunteers during the summer and autumn. This can be a problem in seasons following wet summers that favour the growth of self-sown wheat. The plants that become heavily infected with rust in the autumn provide a source of rust for the new season’s wheat crop. If these conditions are followed by a mild winter and a warm wet spring, then the chances of a leaf rust epidemic are high. Therefore, the chances of a rust epidemic are greatest following a wet summer.

In Australia, due to the absence of the alternate host, leaf rust reproduces asexually. This reduces the variability of the rusts in the field and therefore increases the likelihood that resistant varieties will be effective for a long period of time.

Rust spores are wind-blown and can be spread over large areas in a short time. The establishment of leaf rust epidemics within a crop is favoured by wet conditions and temperatures of approximately 15-22°C.

Management

Resistant varieties

The best way to control leaf rust is to grow resistant varieties. In most parts of Victoria leaf rust has been effectively controlled because of the widespread use of wheat varieties with resistance to this disease.

However, leaf rust occasionally produces new races which are capable of attacking varieties that were resistant when they were first released. These new races occur when a chance mutation occurs in this asexually reproducing fungus. Widespread cultivation of resistant varieties minimises the levels of rust in the environment and reduces the occurrence of new races.

It is important that growers are aware of their varieties’ disease reaction to leaf rust. Variety resistance ratings are available in the Cereal Disease Guide (AG1160). It is important to use a current disease guide as mutations occur in rust from time to time, and resistant ratings are adjusted accordingly.

Cultural practices

Heavy grazing or the use of herbicides during autumn to remove self-sown susceptible wheat will reduce the amount of rust in following crops. However, if spring conditions are favourable for leaf rust development, then even small amounts of rust that survived the autumn can multiply to cause serious yield losses in the spring.

Seed treatments

There are seed treatments available which will suppress early infections of leaf rust. Seed treatments are important in susceptible varieties, especially if they are sown early or following a wet summer favouring growth of volunteers.

Foliar fungicides

There are a number of foliar fungicides registered for the control of leaf rust in wheat. Fungicides should not be regarded as a substitute for growing resistant varieties. They are more of a back up for when a new race of rust evolves and for use in regions where adequate resistance is not available.

A fungicide response is unlikely in resistant or moderately resistant varieties. The earlier in a season that a rust epidemic starts, then the greater the potential yield loss. Crops need to be monitored to detect rust early, as timing is critical for the effective control of rust diseases with fungicides. Rust epidemics can be explosive, and once out of control, can be difficult to contain.

Like the other rusts it is important to apply fungicides early in the epidemic. If a severe epidemic develops early in the season in a susceptible variety, then it may be necessary to make two applications of fungicide. Rust first appearing after ear emergence is less likely to have a significant impact on grain yield.

Stem rust in Australia

Stem rust is an occasional, but devastating disease of wheat. Epidemics occur when there is a carry over of stem rust from the previous season, susceptible varieties of wheat are grown, and warm humid conditions in the spring encourage disease development.

Conditions that favour stem rust epidemics are rare and occur on average once every 16 years in Victoria. However, when conditions are conducive, the disease can cause complete crop loss in susceptible varieties.

Historically, the most severe epidemics in Victoria occurred (in descending order of severity) in 1973, 1947, 1934 and 1955. In 1973, stem rust reduced the Victorian wheat harvest by 25 per cent. It is unlikely that stem rust losses will ever be as severe as in 1973 due to the increased cultivation of stem rust resistant varieties, and the greater availability of effective foliar fungicides. In recent years, there have been few localised occurrences of stem rust.

Following the exceptionally wet January of 2011 there was a large amount of inoculum carry over that resulted in widespread stem rust in Victoria during 2011. In spite of this, the widespread use of chemicals helped minimise losses from this disease.

What to look for

Stem rust is characterised by reddish-brown, powdery, oblong pustules. The pustules have a characteristic torn margin that can occur on both sides of the leaves, on the stems and the glumes. Stem rust spores are much darker in colour than leaf rust spores, which are light brown and don't have torn margins (Figure 1). As the plant matures, the pustules produce black spores known as teliospores. They occur mainly on the leaf sheaths and stem.

Figure 1. Symptoms of stem rust on wheat (left), symptoms of leaf rust on wheat (right)

Conditions favourable to stem rust

Stem rust can occur in all regions of Victoria where susceptible varieties are grown. However, the likelihood of a stem rust epidemic is increased by several factors:

- The build up of stem rust inoculum on volunteer wheat before sowing, both locally and in neighbouring states.
- The widespread planting of susceptible varieties.
- Favourable weather conditions, which includes good spring rains and warm (15-30oC) humid conditions. If the two requirements above are met and there is a wet spring, an outbreak is likely to occur.

Pre-season management of stem rust

Stem rust can be managed using an integrated approach. This includes reducing the inoculum in a district by managing the green bridge, avoiding susceptible cultivars and close monitoring to enable timely fungicide sprays.

Green bridge

Rust can only survive from one season to the next on living plant material (mainly self sown cereals). Therefore, the removal of the green bridge is essential to reduce the amount of inoculum present to infect a new crop. This is why stem rust epidemics have been worse following wet summer/autumns that favour volunteer cereal growth.

Variety selection

Sowing resistant varieties provides the best protection against stem rust. In most parts of Victoria stem rust has been controlled because of the use of resistant varieties.

Stem rust occasionally produces new pathotypes (races) which are capable of attacking resistant varieties. These new pathotypes occur when a chance mutation occurs in this asexually reproducing fungus. Use of resistant varieties minimises the amount of rust in a district, thus reducing the chance of new pathotypes occurring. It is important that growers are aware of a variety's resistance reaction to stem rust. For a comprehensive list of varieties, consult a current disease guide "Cereal Diseases Guide (AG1160)".

In crop management of stem rust

The effects of stem rust can be minimised with the timely application of foliar fungicides. As there is limited information on the management of stem rust in Victoria, the following recommendations for the in-crop management of stem rust are based on experience in Western Australia (Beard *et al*, 2004).

Monitoring

Stem rust is most severe in susceptible varieties when it begins to develop in the crop before flowering and crop losses of 50 per cent are possible. Yield losses from later infections are possible, but not as severe.

As stem rust requires warmer conditions than stripe rust for development, it is advisable to begin monitoring for stem rust from flag leaf emergence onwards. Monitoring will be necessary in seasons when stem rust has been detected locally, or on volunteer plants before sowing.

Guidelines for monitoring for stem rust in wheat crops:

- Inspect wheat crops every 7 to 10 days from flag leaf emergence to early dough grain development. However, if stem rust is detected within a region, then increase inspection frequency to every 4 to 7 days.
- Carefully inspect different plant parts, especially the lower stems, for symptoms of stem rust. Spend at least 15 minutes walking through each wheat crop.
- If stem rust is detected, walk through the paddock in a 'W' pattern and collect 10 stems from 10 random locations (total 100) to determine the percentage of stem rust infection. See Table 1 for control options.

When to spray

The information in Table 1 is a guide for the application of foliar fungicides. Note that this table is not based on Victorian data, but on limited experimental data from Western Australia (Beard *et al* 2004). Fungicides will give better control of stem rust when applied early in the epidemic. A late, low level occurrence of stem rust (ie after mid-dough) will have little impact on yield.

Table 1. A guide for timing fungicide control of stem rust (Beard* et al *2004).

Crop growth stage	Stems infected [A] %	Resistance rating [B] VS, S, MS-S	MR-MS
Before ear emergence	1-5	Spray	Monitor
	>5	Spray	Spray
Ear emergence / mid dough	>5	Spray	Monitor
	>50	Spray	Spray

[A] Based on 100 stems selected in a W pattern across crop.
[B] R= Resistant, MR = Moderately Resistant, MS = Moderately Susceptible, S = Susceptible, VS = Very Susceptible

In 2011 when there were paddocks of self sown wheat heavily infected with stem rust at sowing the prophylactic application of fungicides to susceptible varieties was important in the area wide control of this disease. Such an approach would not be warranted in most seasons.

Choice of fungicide

In Victoria, there are a number of active ingredients (available in a range of products) registered for the control of stem rust.

It is always important to read the chemical label before use. In particular, check that the product is registered, and use the maximum recommended label rate for stem rust control in wheat.

Note products containing tebuconazole break down relatively slowly in plants, and users must observe the product label restrictions regarding the total amount that can be applied to one crop per season. This will ensure harvested crops don’t exceed the tebuconazole maximum residue limit (MRL) in cereal grains. See *Taking Care with Foliar Fungicides* for more information. As sprays for stem rust may be applied late in the season, it is extremely important to know the harvest withholding period for the chemicals, which can vary from 4 to 6 weeks.

Life cycle

Stem rust (caused by the fungus *Puccinia graminis*) can only survive from one season to the next on a living host. It does not survive on stubble, seed or soil. The most important hosts are susceptible wheat, but it can also survive on barley, triticale, and some grasses. Carry over on wheat from one season to the next is greatest during wet summer/autumns.

Rust spores are wind-blown and can be spread over large areas in a short time. Wet conditions and temperatures of approximately 15-30°C favour the establishment of stem rust within crops. Stem rust usually becomes evident later in the season than stripe rust.

Disease management of yellow rust

Breeding resistant varieties is the most cost-effective method to control this rust. Fungicides are available but vary in availability depending on their registration restrictions by national or state governments.[5g][6g] Development of varieties resistant to the disease is always an important objective in wheat breeding programs for crop improvement. These resistance genes, however, became ineffective due to the acquisition of virulence to that particular resistance gene rendering the variety susceptible. [7g]

YELLOW rust (*Puccinia striiformis*) is a hazard to the cultivation of wheat (*Triticum aestivum* $2n = 6x = 42$) in many temperate regions. The most economic method of limiting losses of yield caused by the disease lies in the cultivation of varieties with genetically determined resistance to infection. Most current varieties owe their resistance to the activities of a few major genes which they carry in various combinations. New sources of resistance, however, must be sought continually because mutation or somatic recombination in the pathogen can give rise to genetic variants against which particular resistance genes or combination of genes, in current use, cease to be effective.