NSW DEPARTMENT OF
PRIMARY INDUSTRIES

# Stripe rust: Understanding the disease in wheat

**Disease Management**

Right: Fig. 1. Stripe rust on susceptible wheat.

Jan Edwards


## *SUMMARY*

Stripe rust survives year-round on living wheat. Some other cereals and grasses can play a minor role in its survival. Wind spreads spores within crops, and over long distances. The rate of development of stripe rust depends on moisture and temperature: it is most active in autumn and spring in the NSW wheat belt.

Growing resistant varieties keeps the level of stripe rust low, so that other controls are not required. However, many current varieties are susceptible, and other controls are needed.

Depending on variety, location and yield potential, control should include a mixture of:

- Eradicating volunteer wheat growing over summer.
- Sowing varieties with the maximum stripe rust resistance that also meet the desired agronomy, marketing quality, and reactions to other diseases.
- Ensuring purity of seed source.
- Treating seed or fertilizer with fungicide for early-sown winter wheats to prevent autumn build up of stripe rust.
- Treating seed or fertilizer with fungicide to delay the onset of stripe rust in susceptible to moderately resistant wheats, or early spraying to control infections in autumn or early winter.
- Monitoring stripe rust activity in your crops.
- Spraying crops with fungicide if the potential yield loss exceeds cost of spraying.


## *Distinguishing the wheat rusts*

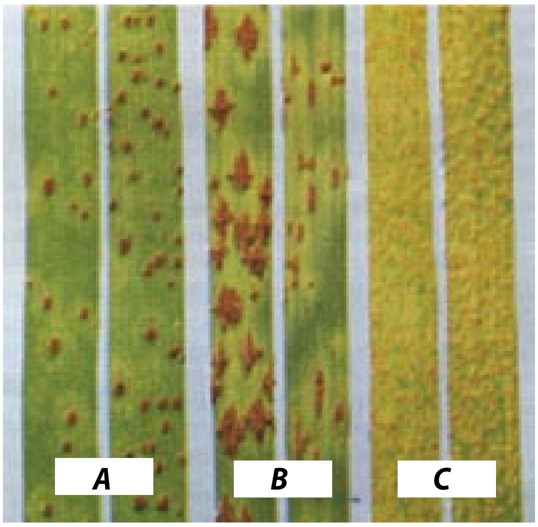
| Pustule character | Stripe rust | Leaf rust | Stem rust |
|---|---|---|---|
| Colour | Yellow | Orange brown | Reddish brown |
| Shape | Small, circular, densely packed on seedling leaves and in yellow stripes running along the leaf in older plants | Circular to oval in random pattern on leaf | Oval to elongated with conspicuously tattered edges, random pattern on leaf |
| Location on plant | Chiefly on upper surface of leaf, but also on leaf sheaths, awns and inside of glumes (head infection) | Chiefly on upper surface of leaf and leaf sheaths | On both sides of leaf, on leaf sheaths, stems and outside of head |

Because of the colour differences between them, these three rusts are called 'yellow rust', 'brown rust' and 'black rust' in some countries.

Gordon Murray

Above: Fig 2. Stripe rust spores rubbed from an infected leaf.

Right: Fig 3 . Wheat rusts on seedling leaves. A: leaf rust; B: stem rust; C: stripe rust.




Plant Breeding Institute, Cobbitty

## RECOGNISING STRIPE RUST

Stripe rust is one of three rusts that attack wheat. The others are stem rust and leaf rust.

Rusts get their name from the characteristic dusty yellow, orange or brown spore pustules that resemble fresh rust on iron. A quick test is to wipe along the infected leaf or stem with a white cloth, tissue or finger and look for the 'rust' stain.

The characteristic colours of the rusts are freshest in the morning when new spores of stripe rust appear distinctly yellow. However, the colours can become duller by the afternoon, when it can be difficult to tell stripe rust and leaf rust apart. As the wheat plant nears maturity, all three rusts can produce a black spore stage which does not rub off.

The rusts are easy to distinguish from other wheat diseases when the pustules are young. However, as leaves die it can be difficult to separate rust damage from other causes, including other leaf diseases, nutrient deficiencies/toxicities, physiological leaf death and adverse seasonal conditions.

If in doubt, consult your adviser or send samples to the Plant Health Diagnostic Service of NSW Department of Primary Industries.

### Causes of wheat rusts

The wheat rusts are caused by three species of the fungal genus *Puccinia*: stripe rust by *Puccinia striiformis* f.sp. *tritici*; leaf rust by *Puccinia triticina*; and stem rust by *Puccinia graminis* f.sp. *tritici*. Generally, these pathogens are confined to wheat but can occur to a small extent on other cereals and grasses.

Stripe rust established in eastern Australia in 1979, while a second introduction to Western Australia in 2002 had spread to the east by 2003.

## STRIPE RUST DISEASE CYCLE

Wheat stripe rust can develop on triticale, barley, barley grass, brome grass and some other grasses, but wheat is the main host.

Wind spreads spores of stripe rust from pustules that develop on infected leaves. If the spores land on another living wheat leaf, they can germinate and infect the leaf. The rust grows inside the leaf and then produces pustules containing new spores.

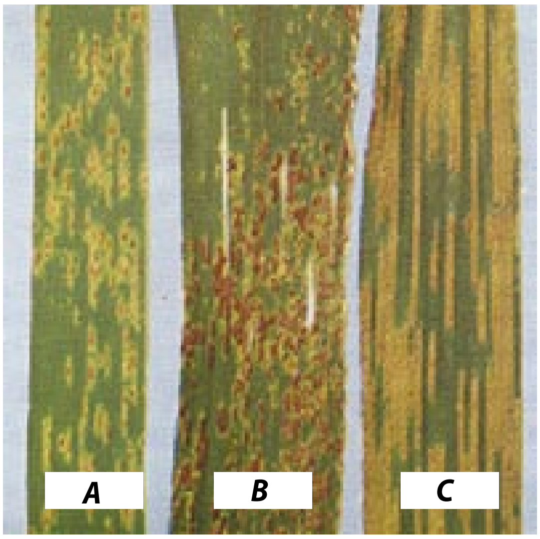
### Spread

Wind is the main means of spread or dispersal for stripe rust. The spores are produced in huge numbers in pustules on the upper surface of leaves. Once the spores become airborne, their spread is a matter of chance. Most will land on soil or other plants, while some stay airborne until sunlight kills them in a few days. However, they are produced in such high numbers that some land on other living wheat plants.

During high humidity in winter, most spores remain in small clumps: these are relatively heavy and fall out of the air quickly, so their spread is mostly over very short distances, leading to the 'hot-spots' of infection seen in crops in late winter and early spring.

In lower humidity, spores disperse singly in the air and can travel for much longer distances. This may result in a uniform pattern of disease development in crops seen from mid spring. Long distance dispersal means that rust developing in any part of the wheat belt can spread rapidly to other areas. Some travel very far: spores produced in Western Australia can reach eastern Australia while those from eastern Australia have reached New Zealand.

Spores of stripe and other rusts can also adhere to clothing, so that travellers can inadvertently carry them. It is likely that stripe rust entered Victoria on an air traveller's clothes from Europe in 1979, and Western Australia from North America in 2002. For this reason, air travellers who have visited agricultural enterprises are strongly advised to wash



Plant Breeding Institute, Cobbitty

Right: Fig 4. Wheat rusts on adult leaves. A: leaf rust; B: stem rust; C: stripe rust.

or dry clean clothing immediately on return to Australia to reduce the chance of introduction of rusts and other plant diseases.

## Infection

Once released from a leaf, spores can live for only a few days. A few land on wheat where they can infect if conditions are suitable. Infection requires high humidity for 4 to 6 hours at 10 to 15°C, with increasing time required at lower and higher temperatures. Infection seldom occurs below about 2°C, and ceases above 23°C.

After infection, the pathogen grows within the leaf, deriving its nutrients from living wheat cells. Growth is most rapid at 12 to 15°C, reducing to almost nil at 3°C and above 25°C. If temperatures are outside the range for growth for any part of the day, the rust stops growing for that time but resumes growth when the temperatures become favourable again at other times of the day.

Below: Fig. 5. 'Hot-spot' of stripe rust in a wheat crop.


John Francis

## Sporulation

At 12 to 20°C, the fungal pathogen grows for about 14 days (shorter in some highly susceptible varieties) before the pustules erupt through the leaf, with longer times of up to 80 days at 3°C, and cessation of growth much above 25°C. The time between infection and appearance of symptoms is termed the latent period.

Spore production is favoured by high humidity and similar temperatures to the other stages of growth. Thus fresh spores are usually seen in the morning because cooler temperature and still air are more conducive for sporulation.


Plant Breeding Institute, Cobbitty

Above: Fig. 6. Stripe rust within a wheat head. Yellow spores pile up on the grain but the seed is not infected.

## Head infection

Stripe rust can develop on the inside of the glumes, lemma and palea (cup-shaped bracts that enclose the seed). Most of this infection occurs when the florets open at anthesis. Spores enter the open floret, infect and develop within the lemma and palea, and so accumulate, often piling up on the top of the seed as it grows. The seed in the infected spikelet can be smaller, but there seems to be little effect on seeds growing in uninfected spikelets in the rest of the head. Infection of the seed does not occur, and hence there is no seed transmission of stripe rust.

Head infection can be common in some moderately susceptible and susceptible wheats. If fungicide spraying is done before head emergence, the heads are not protected: if there are large numbers of spores blowing into the crop, head infection can occur. Spraying after head emergence and before anthesis will contribute to control of head infection, but spraying after head infection does not.

### *Temperature and stripe rust development*

Temperature affects all parts of the disease cycle in a similar way. At ideal temperatures, the cycle from spore infection to new spore production takes about 12-14 days. Providing there are susceptible wheat plants and sufficient humidity, the average daily temperature (**average of the maximum and minimum temperatures each day**) has the biggest effect on development of stripe rust.

The graph below shows the rate at which stripe rust can develop each month for some locations in the wheat belt. For the main wheat belt, temperatures are ideal for stripe rust in the autumn and spring and it can have over 2 cycles per month at those times. Its rate of development drops to less than 1 cycle every two months in the heat of summer and slows to a lesser extent in the colder winter temperatures. Autumn temperatures become suitable earlier in the south while warming weather becomes unsuitable for development earlier in the spring in the north. Winter temperatures are higher in the north, allowing stripe rust to develop quicker there during winter. Consequently, stripe rust is usually seen earlier in the north than the south.

Although only small amounts of wheat are grown on the Tablelands, the mild summer temperatures at locations such as Orange mean that stripe rust may develop normally there over summer. However, the colder Tableland temperatures slow development more than in the main wheat belt in winter.

### *Green Bridge*

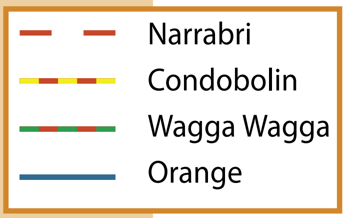
Stripe rust survives all year round by having a continuous supply of living host plants. Thus volunteer wheat plants growing over summer provide a 'green bridge' for stripe rust to survive, although high temperatures mean that there are likely to be only trace amounts present over summer, making it very difficult to find at that time of year. However, once average daily temperatures fall in autumn, rust development accelerates.

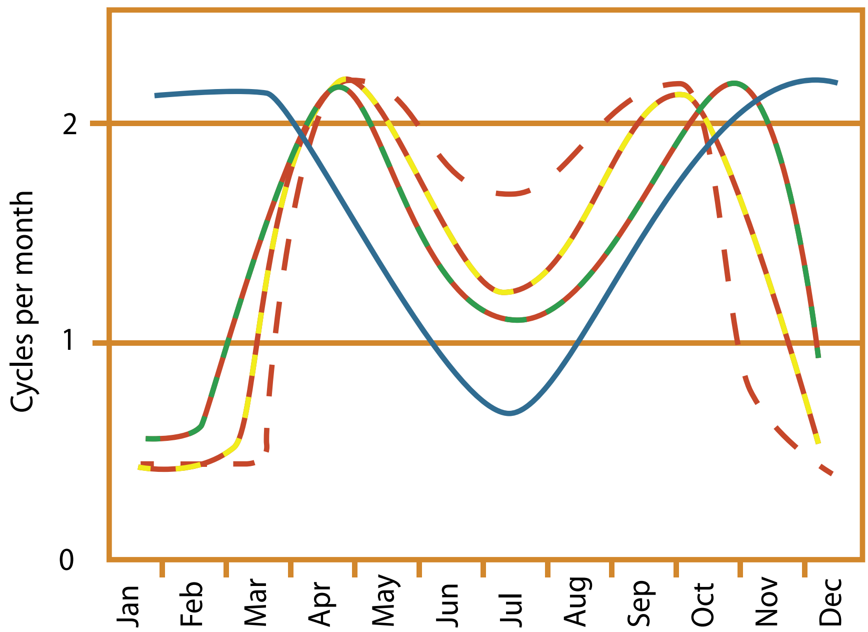
A high population of susceptible wheat in the autumn allows the possibility for stripe rust to build up and the epidemic to begin earlier, and so become more damaging. A key to reducing the threat from stripe rust is to remove volunteer wheats by grazing, spraying or cultivation before the next season's crops are sown. This strategy will not eliminate all stripe rust, because some wheat plants may survive along roadsides, etc. However, the widespread elimination of the green bridge throughout a district substantially reduces the early season pressure from stripe rust, delaying the epidemic and helping in-crop management.

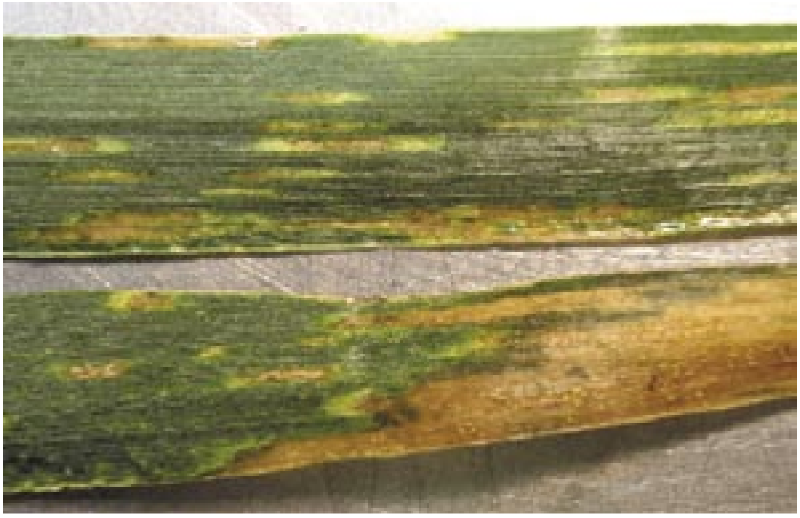
Late summer and early autumn rains can promote early growth of volunteer wheat. Where this is from a highly-susceptible variety, these volunteers pose a particular threat, allowing rapid build-up of stripe rust in autumn, unless they are removed.

Early-sown crops also provide a green bridge for stripe rust. Fungicide-treated seed or fertilizer treatments will protect these crops and reduce the chances of an early build-up of stripe rust. Because wind can carry spores for long distances, a build-up of stripe rust in one early-sown crop threatens later crops over a very wide area.

Below, right: Fig. 7. The potential number of cycles of stripe rust per month varies through the year due to changing temperatures, and differs between locations as shown for Narrabri in the northern NSW wheat belt, Condobolin in the central wheat belt, Wagga Wagga in the southern wheat belt, and Orange, located on the Central Tablelands where only small amounts of wheat are grown.





Gordon Murray

Above: Fig. 8. Adult plant reaction developing on flag leaves. The leaf has died around developing stripe rust, leaving dead stripes. Some old rust pustules can be seen in dead areas on the lower leaf.

Where most farmers adopt a combination of controlling volunteers and protecting early-sown crops, the stripe rust population will be minimal, delaying the start of the epidemic and making spring control simpler.

Keeping stripe rust at a low level is also important for reducing the appearance of new pathotypes.

## *DISEASE RESISTANCE IN WHEAT*

The reaction of a wheat variety to stripe rust depends on two forms of resistance. The first, seedling resistance, operates throughout the life of the plant. The second, adult plant resistance (APR), develops as the plant matures. APR usually develops some time during the booting stage, but can develop earlier during stem elongation, or be delayed until early head emergence, depending on variety and growing conditions.

### Seedling resistance

Seedling resistance is highly effective against pathotypes of stripe rust that are not virulent on it. It is usually controlled by a single gene. Unfortunately, stripe rust is a highly variable pathogen and continually develops new pathotypes (races, strains) that can overcome single-gene seedling resistance. A new pathotype emerged in the 1983 epidemic in eastern Australia, and became a major problem on some varieties in 1986. Other examples of pathotypes are given on page 7.

The wheat variety H45 has highly effective single gene resistance. Unfortunately, a pathotype that attacks this resistance was detected in 1986, well before H45 was released. For some years after release there was no problem, but the widespread sowing of H45 led to the build up of the virulent pathotype, and H45 became severely affected in 2002, and more widely in 2003.

One form of seedling resistance in several current varieties is the VPM or Yr17 resistance gene. This gene makes these varieties highly resistant to all current pathotypes of stripe rust except one. This last pathotype is presently uncommon, but the experience with H45 tells us to expect this pathotype to become more common if the VPM varieties are more widely grown.

Wheat breeders have found that stripe rust overcomes single-gene resistance relatively quickly unless it is combined with other genes for resistance. Several of the VPM varieties have good adult plant resistance that can help protect the variety should the seedling resistance be overcome.

### Adult plant resistance (APR)

Combinations of APR have proven to be the most effective resistance under Australian conditions. APR develops as the plant grows: it can start from stem elongation to heading. In 2003 and 2004, APR developed in most varieties with this resistance at late booting to early heading.

When most of the area is sown to varieties with effective APR, stripe rust has not been seen until after flag leaf emergence and little damage has occurred. However, if the epidemic begins before flag leaf emergence, damage to varieties with APR can be more than 20%.

In established infections, the wheat cells around the infection die when APR starts to become effective. This leaves dead stripes and patches in the leaf. With new attempted infections, APR stops early development of the rust. Some plant cells may die: with low levels of infections no damage is seen, but if the leaf has large numbers of spores attempting to infect it, dead patches appear. These are most obvious if an APR variety is growing alongside a susceptible one and large numbers of spores blow onto it.

The new 'WA' pathotype is more damaging on many varieties than earlier pathotypes. This means that the reaction score for these varieties is now 1 to 3 units less than in previous years, reducing some from moderately resistant (6 or 7 rating) to moderately susceptible (4 or 5 rating). H45 was moderately susceptible to susceptible (3 or 4) to the old pathotype, but is highly susceptible (1) to the 'WA' pathotype.

Right: Fig. 9. Varying levels of adult plant reaction to stripe rust:

Resistant to moderately resistant

Moderately resistant

Moderately susceptible

Moderately susceptible to susceptible

Susceptible

Very susceptible

All photos this page: Plant Breeding Institute, Cobbitty

The stripe rust ratings issued by Sydney University's Plant Breeding Institute provide the adult plant reactions to the widely distributed 'WA' pathotype and to the VPM-attacking pathotype. On this scale, an 8 or 9 (resistant) means that the variety is expected to carry seedling resistance.

### Pathotypes of stripe rust

Many pathogenic variants (pathotypes) have developed spontaneously from the original one that arrived in eastern Australia in 1979. The most damaging ones have been:

- the A+ pathotype (first detected in 1981), which caused widespread damage on Egret in the 1983 epidemic in southern and central NSW.
- the Yr6 virulent pathotype (1983) that severely damaged Bindawarra and Millewa in 1986.
- the Yr7 virulent pathotype (1986) that attacks H45.
- the Yr17 virulent pathotype (1999) that has caused problems to varieties protected only by the VPM resistance (QAL2000, Camm).

The damaging 'WA' pathotype that entered Western Australia in 2002 is now the main pathotype present in eastern Australia. If this pathotype behaves in the same way as the original one, we expect new pathotypes to evolve from it over the next few years.

### Monitoring rust pathotypes

The published information on varietal reactions to stripe rust is based on the reactions to the common and widespread pathotypes. If you observe a more severe reaction on a variety than its rating would indicate, it may be the result of several factors, including the possibility of a new pathotype.

Each year, Sydney University's Plant Breeding Institute surveys Australia for pathotype variation in all the cereal rusts. The survey relies heavily on cooperators sending rust samples for pathotype identification.

If you notice any unusual or unexpected development of rust, please report it. It is also important that the first sightings of rust in a district be sent for the survey.

Rust samples should be sent in paper envelopes (not plastic bags), marked with your name and address and the date, location and variety, if known. Leaves and stems with active pustules are required. They should be posted without delay to:

Rust Survey, Plant Breeding Institute Cobbitty

Private Bag 11, Camden, NSW 2570.

### Stripe rust and nitrogen

The nitrogen status of a wheat crop affects the level of stripe rust. This is independent of the effect of nitrogen creating a denser canopy with higher humidity that would additionally favour rust.

Very little stripe rust develops in nitrogen-deficient crops, and the leaves seem to develop an early and very effective adult plant reaction. Conversely, APR seems to be delayed in crops with high nitrogen status.

## *LOSSES FROM STRIPE RUST*

Damage from stripe rust depends on the susceptibility of the wheat variety, how early the epidemic begins, the amount of stripe rust that develops and temperature during grain filling. Under average conditions in southern NSW with epidemics starting (1% leaf area diseased) from flag leaf emergence to mid flowering, the potential percentage losses are tabulated below.

Losses will be less if the temperature during grain filling is higher than average, and greater if the temperature is lower than average. Hence, yield losses in northern NSW, which generally has higher temperatures during grain fill, would be expected to be lower than these figures typical for southern NSW. The loss from stripe rust is also less if moisture stress affects grain development.

This table shows the benefits of moving from a susceptible to a more resistant variety. It also shows the benefits of any actions that delay the onset of an epidemic. Depending on the potential yield and each farmer's acceptance of risk, spraying becomes economical when the yield loss exceeds about 10%.

Stripe rust affects yield by reducing the green leaf area. This reduces the sugar supply to the developing seed, so that when severe, stripe rust will result in smaller seeds, an increase in screenings and possible downgrading at receival.

The flag leaf and the second leaf are the most important leaves for producing sugars for the developing grain. The longer that these leaves remain green, the higher the yield is likely to be.

**Under average conditions in southern NSW with epidemics starting (1% leaf area diseased) from first node to mid flowering, the potential percentage losses are tabulated below:**

| | Stripe rust reaction | | | |
|---|---|---|---|---|
| **Epidemic start** | **2 (S)** | **4 (MS)** | **6 (MR)** | **7 (R-MR)** |
| flag leaf (GS39) | 75 | 45 | 15 | 5 |
| mid boot (GS45) | 65 | 25 | 7 | 2 |
| awn peep (GS49) | 50 | 10 | 3 | 1 |
| mid heading (GS55) | 40 | 5 | 2 | 0 |
| mid flowering (GS65) | 12 | 2 | 1 | 0 |

## *MANAGING STRIPE RUST*

Stripe rust management should aim to protect the flag leaf and the second leaf to minimise losses. Strategies to achieve this are to delay the onset of the epidemic and then to reduce its rate of development.

Thus effective strategies for managing stripe rust are:

- Delay the onset of the epidemic by destroying the green bridge.
- Sow the most resistant variety available that meets agronomic, quality and other disease resistance requirements.
- Ensure purity of seed source, and maintain records of varieties sown in each paddock.
- Protect young crops, especially early-sown ones, from autumn and winter infections with fungicide seed or fertilizer treatments.
- Monitor crops so that early decision can be made on whether fungicide sprays would be beneficial.
- Spray before the disease becomes severe in the crop.

### Public risk disease

Because stripe rust can spread rapidly from one farm to another over long distances, actions by one person can have an effect on others, making stripe rust a 'social' or 'public risk' disease. Regardless of the controls used, maximum benefits occur if all farmers adopt effective management strategies for stripe rust.

### Farm hygiene/breaking the 'green bridge'

The opportunities for rust survival prior to main season cropping can be minimised by breaking the 'green bridge' through grazing, herbicide spraying or cultivating/slashing volunteer wheat. This should be done throughout a district by late summer or if the break is early, at least two weeks before the next season's crop emerges.

The growing of resistant wheats will also reduce the general susceptibility of the plants in the green bridge, providing an even more effective way of reducing the carryover of stripe rust from one year to the next.

Uncontrolled volunteer wheat, particularly susceptible varieties, on one farm is a threat to neighbouring farms and, with longer distance spread, to the whole area. Thus it is vital that all farmers reduce susceptible volunteers to a minimum.

### Resistant varieties

Various systems are used to describe a wheat variety's reaction to stripe rust. This publication uses a 1—9 scale where 1 = very susceptible and 9 = very resistant (note: another scale in common use expresses the reactions in reverse).

Ideally, wheat varieties with a stripe rust reaction of 5 or less should not be grown. Stripe rust ceased to be a problem after 1984 when farmers stopped growing such varieties. At present, farmers have only a limited range of varieties with rating of 6 or better, so less-than-ideal varieties will continue to be grown in the short term. However, in the interim period, great benefit can still be obtained by moving away from very susceptible (1) varieties to moderately susceptible (4 or 5) ones.

Stripe rust will develop more slowly with increasing levels of resistance. With a slower-developing epidemic, the farmer can take more time deciding whether to spray, and the fungicide is likely to be more effective in controlling the disease. An additional benefit arises because resistant varieties generate fewer spores in volunteers both over summer and in the crop: this will delay the onset of the disease, decrease the rate of spread within the season and reduce potential losses.

The latest information on the reactions of wheat varieties to stripe rust and other important diseases are updated in each year's *Winter Crop Variety Sowing Guide* and in bulletins released by Sydney University's Plant Breeding Institute, both of which are available from local offices of NSW Department of Primary Industries.

## Seed purity and accurate records

During the recent stripe rust epidemics, reports occurred of various resistant (8) wheats being severely affected by stripe rust. This created confusion within the industry as to whether a new pathotype had developed and resulted in some panic spraying.

Other causes of high levels of stripe rust in a supposedly resistant variety, apart from a new pathotype, have been:

- mistaken identity of the variety
- 'off-types' within the crop so that some plants are infected and others are healthy.

## Fungicides

The fungicides registered for control of stripe rust are triazoles or, more recently, a mixture of a triazole with a strobilurin. These triazole fungicides are absorbed and translocated in the plant, so are called systemic fungicides. Different triazoles are absorbed at different rates and can move in the plant at different rates. The properties of each determine their suitability for application as seed treatments, with fertilizer or as foliar sprays.

Fungicides mentioned in the following sections are those registered for use in NSW as of January 2005. The range of fungicides is continually being extended: we advise you to check which products are available each season.

## Seed treatments

Four active ingredients are currently registered as seed treatments for the control of stripe rust in seedlings: flutriafol, triadimenol, triticonazole and fluquinconazole. Most are available under more than one trade name and formulation. The rates of application vary depending on which diseases require control, with generally the higher rate of application preferred for stripe rust.

*Seedling protection treatments*

The first three products provide control of stripe rust for about 8 weeks after sowing, which delays the onset of the disease within a crop. The length of protection varies: experience has shown that stripe rust will begin to develop during the stem elongation stage between first node (GS 31) and flag leaf emergence (GS 37).

These treatments appear to have most value for early-sown crops to provide protection during autumn and for late-sown crops with good APR.

*Plant protection treatments*

Fluquinconazole is taken up by the seedling more slowly than the other fungicides, so a higher rate can be applied, giving control for up to 12 weeks after sowing. In practice, control seems to have been good to about the booting stage (heading stage in later sown crops), but susceptible crops should be watched closely from this time, in case a supplementary fungicide spray is required.

This treatment will also provide protection from take-all. Thus it appears most useful for replacing the need for an early spray, and where protection from take-all is desirable.

Right: Fig. 10. Stripe rust produces spores in enormous numbers on susceptible varieties, covering the soil under hot-spots. Early control is essential to prevent severe yield loss in the infected crop and to reduce the threat to other crops.

Gordon Murray

*Caution*

One disadvantage of these seed treatments is the potential they have for reducing the coleoptile (shoot) length and therefore the seedling's ability to emerge if sown deeply. This is more likely with small seeds such as develop in a dry finish. The risk of seed damage is greater with flutriafol and triadimenol, with triticonazole and fluquinconazole being safer. However, we advise caution with small seed, and to avoid deep sowing and trifluralin that can also reduce coleoptile length.

If the wheat is to be grazed, care must be taken to check the withholding period for grazing on the label. These periods differ among the seed treatments.

### In-furrow fungicides

The active ingredient flutriafol is registered for application to fertilizer as an 'in furrow' treatment. The growing plant takes up the fungicide over a long period, so this treatment provides control for most of the growing season. Susceptible crops will need to be monitored from about heading onwards. The decline in protection is more gradual than that with the seed treatments.

This treatment appears most suitable for farmers who wish to avoid spraying moderately susceptible to moderately resistant (4-6) varieties or to replace the early sprays on very susceptible to susceptible (1-3) varieties. This treatment also provides protection from take-all.

Once again you will need to check the withholding period before grazing.

In-furrow application of flutriafol does not protect the plant from loose smut and bunt. Thus we advise you to use a low-cost seed treatment to control these seed-borne diseases in combination with the in-furrow treatment.

### Fungicide spraying

Four triazoles (flutriafol, propiconazole, tebuconazole and triadimefon), and two composites, (azoxystrobin plus cyproconazole and propiconazole plus cyproconazole), are registered under several trade names as fungicide sprays to control stripe rust. All give excellent control providing they are applied early in the epidemic.

For best control the sprays need to be applied evenly to the leaves and at the water volume recommended on the label. Spraying can be by ground or air. With ground application, the boom must be high enough so that the spray fans overlap on the uppermost leaves. Spray droplets must be in the fine to medium range to ensure that they penetrate the crop canopy.

All products are rapidly absorbed into the plant after application. They become systemic in the plant but move only in the direction of water flow. Thus fungicides will move to the leaf tips but do not move from lower leaves to upper leaves or the head. Portions of leaves, whole leaves and heads that develop after spraying will not be protected.

Flutriafol, propiconazole, cyproconazole and triadimefon move fairly quickly to the leaf tips so that their concentration drops and they stop protecting the leaf after about 3 weeks. Tebuconazole moves more slowly and provides about 4 weeks protection, while the azoxystrobin is more immobile so that this composite fungicide provides up to 5 weeks protection.

Once applied, the triazoles can stop development of early infections of stripe rust ('kick back' activity) but they do not stop infections that are more than about one week old. These older infections will continue to develop as dead stripes on the leaf for up to a week after spraying and can result in a doubling of the damaged leaf area. Established pustules will stop producing spores quickly.

Once the effectiveness of the fungicides declines after 3 to 5 weeks depending on the product, stripe rust will start developing again from the ends of old stripes and from new infections. A second application of fungicide may then be needed.

### Crop monitoring for stripe rust

Decisions on spraying depend on finding stripe rust, as there is no point spraying unless there is a threat to the crop. However, it is difficult if not impossible to find the first infections of stripe rust in a crop. These infected leaves will be rare, and in the time it takes from infection to pustules, new leaves will have grown and will obscure rust on lower leaves. Once the flag leaf has emerged, pustules can easily be seen on the top leaf.

Although early winter infections will probably go unnoticed, these will develop into 'hot-spots' which can often be seen as a yellow patch in the crop. Once stripe rust becomes established in other crops in the district, stripe rust will be more uniform in the crop and you will need to walk through sections, stopping every 10–20 paces to look into the crop.

Crops should be inspected every two weeks during winter, changing to weekly from mid-August as the potential rate of stripe rust development increases. More frequent checks should be done once stripe rust is reported in your area. If you see stripe rust and you are not aware of other reports in your area, please report it to your district agronomist. Your report will warn others and allow them to be better prepared.

At early stages, the level of stripe rust is best assessed by counting the number of infected leaves per 100 green expanded leaves. Walk in a 'W' pattern through the crop, stopping every 20 paces to collect some tillers until you have about 100 tillers (300–400 expanded green leaves). Count the number of leaves with any stripe rust and the total number of green leaves, then calculate the percentage with stripe rust.

## Guidelines for spraying

The table on potential losses from stripe rust (see page 8) gives overall guidance on whether it will pay to spray. These estimates are for average crops in an average season. Each case will be somewhat different. Some factors that affect the economic return from spraying are:

- Stage of development of the crop when stripe rust is first observed.
- Likely temperature from observation to grain filling.
- Frequency of dew periods in the last two weeks and expected moisture in the coming weeks.
- The variety's expected reaction to stripe rust.
- The amount of stripe rust present when first observed.
- The potential yield and value per tonne of the crop.
- The cost of the fungicide and its application.

Your adviser or district agronomist can help in assessing whether spraying is warranted. Many of them will have the *RustMan* program to help them estimate the likely effect of stripe rust on yield, and the economic benefit of fungicide applications.

## Timing of fungicide sprays

For best results, foliar fungicides should be applied before stripe rust becomes well-established in the crop. Once stripe rust has been reported in your district, the optimum timing of application depends in part on the reaction of the variety to stripe rust and on the growth stage of the crop. You will also need to consider the possible damage from the disease to decide if spraying is likely to be cost-effective.

*Susceptible wheats (rating 1 to 3)*

Stripe rust can develop explosively in susceptible and very susceptible varieties. If current and forecast conditions are suitable for stripe rust, it may be safer to spray when stripe rust is detected in your district, particularly if it is spreading quickly in other crops.

If you are monitoring crops, you should aim to spray when hot-spots are first seen, or when the incidence of stripe rust is 10–20 infected leaves per 100 green leaves. The epidemic will be developing very quickly, and it will be difficult to control if you wait until it reaches 30-40 leaves per 100.

Depending on seasonal conditions and yield potential, spraying is likely to be cost-effective if the epidemic begins at any time up to late anthesis. The potential for two, and sometimes three, applications of fungicides should be included in the budget when growing susceptible varieties.

*Moderately susceptible to moderately resistant wheats (rating 4 to 7)*

Monitor the crop and wait until stripe rust reaches 1% of leaf area covered. This is when either hot-spots are well developed and stripe rust is just starting to become general in the crop, or when it affects 30–40 leaves per 100 green leaves. Depending on seasonal conditions and yield potential, spraying is likely to be cost-effective if the epidemic begins at any time up to late booting.

*Resistant wheats (rating 8, 9)*

These should not require spraying. If you observe stripe rust in these, it may be a new pathotype (check that the rust is not just on off-types and that the variety has been correctly identified). Report this to your district agronomist or adviser and ensure that samples are sent for testing. Check the likely rate of development of stripe rust and decide whether to treat the variety as susceptible.

*Caution*

Regardless of variety, spraying should be done before stripe rust reaches 5% of leaf area on the flag leaf. Once this level is reached, stripe rust becomes very difficult to control. In addition, the leaves will continue to die for about a week after spraying because infections continue to develop.

Late spraying of severe stripe rust in susceptible wheats has given an economic response in crops with high yield potential, but it is far less than that if the spray had been applied earlier.

NSW DEPARTMENT OF
**PRIMARY INDUSTRIES**

## *Time of onset of epidemic*

*Before stem elongation (GS 30)*

Fortunately such early starts are rare. They are best controlled by seed or fertilizer treatment. Foliar fungicides can be applied at the low rate, but will need to be repeated at 3–4 week intervals to protect newly emerging leaves. If convenient, this early spray can be combined with a scheduled herbicide spray to minimise cost of application.

Consider grazing the crop to remove infected leaves: re-infection is slower during winter, so monitor the crop for new stripe rust as usual.

*Stem elongation (GS 30–33)*

Consider the yield potential and APR of the crop. If satisfactory, spray with the low rate of an inexpensive fungicide. This will slow the epidemic. Newly emerging leaves will not be protected, so a second spray at flag leaf emergence (GS 39) may be required.

*Flag leaf emergence (GS 37–39)*

Spraying at this time poses a dilemma. The spray will slow the epidemic, but the flag leaves that emerge after the spraying will not be protected. These will need spraying within one week of emergence to eradicate stripe rust infections, and potentially 3 weeks later. It may be better to wait a few days until the flag leaf has fully emerged before spraying, unless an expected weather change or unavailability of spraying contractors, etc., would delay spraying longer.

Where stripe rust is established on the lower leaves and there are frequent dews or a period of showery weather is expected, spraying at the low rate will protect the exposed leaves and hold the disease until the flag leaf is fully emerged. Re-evaluate the need for spraying within one week of flag emergence.

*Flag leaf emerged to late booting (GS 39–49)*

It is critical to control stripe rust on the top two leaves, as these contribute most to the yield. A spray will protect leaves for 3–5 weeks depending on fungicide, variety and seasonal conditions. Re-evaluate the need for a second spray to continue protection of these leaves through grain filling.

*Heading (GS 51–59)*

Consider a spray after head emergence and before flowering to protect the heads and flag leaves of very susceptible to moderately susceptible varieties (ratings 1–5).

*Flowering onwards (> GS 63)*

Yield reductions from very late commencing epidemics are unlikely to be large enough to warrant spraying in most situations. The exception is high-yielding crops of susceptible varieties, where late spraying has given an economic response.

## Deciding the best control package

There is no one 'correct' control for stripe rust. Discuss the options for your particular cropping system with your adviser.

Control actions taken before and at sowing are 'strategic': you decide on previous experience and the outlook for the season as to the best option.

Control actions during the season are 'tactical', responding to the developing situation. Your District Agronomist or adviser will have the *RustMan* program to estimate the likely damage that stripe rust could cause, and the likely benefit from spraying to help you in your decision.

## *Disclaimer*



## *Authors*


Dr Gordon Murray, Principal Research Scientist, Wagga Wagga Agricultural Innovation Park, NSW DPI

Dr Colin Wellings, Principal Research Scientist, seconded from NSW DPI to The University of Sydney, Plant Breeding Institute Cobbitty

Dr Steven Simpfendorfer, Plant Pathologist, Tamworth Agricultural Institute

Mr Chris Cole, Manager, Industry Development, (Broadacre Cropping), Orange



Production by Michel Dignand, Information Delivery Wagga Wagga

5617 January 2005