Factors affecting the severity of Fusarium wilt: environmental aspects of the disease.

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Fusarium wilt of Cotton: pathogen, plant and environment

Fusarium wilt is an economically important disease of cotton in Australia. Disease occurs at the intersection of pathogen, plant, and environment (Figure 1). In the case of Fusarium wilt, the disease can only occur when cotton (the plant), infected by the soil-borne fungus *Fusarium oxysporum vasinfectum* (*Fov*) (the pathogen), experiences environmental conditions that favour the pathogen above the plant. Current control measures are by and large focussed on limiting the spread of the pathogen, and developing new cotton varieties with increased resistance to the disease.

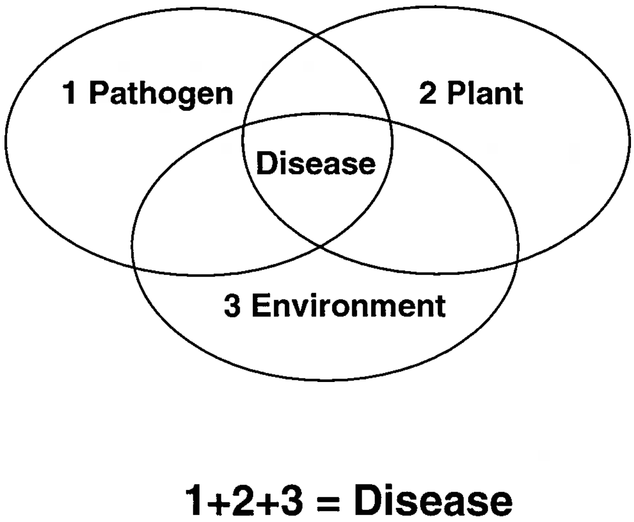

Figure 1. Disease is the interaction of pathogen, plant and environment.

Environmental aspects of the disease

It follows then that if we are to develop an effective and holistic integrated disease management strategy for Fusarium wilt, we need to investigate environmental aspects of the disease. The environment consists of an innumerable quantity of uncontrollable variables. For example, we cannot choose when it rains and we cannot to a large degree manipulate air and soil temperatures. We can however choose when to introduce cotton into an environment where the pathogen is present. It is generally considered that cooler conditions early in the season favour disease. Thus, we may be able to avoid conditions favourable to disease by planting later. We can also choose whether we plant into wet or dry soil. Thus, whether we pre-irrigate before or water-up after sowing may also impact upon disease.

Environment and the "visibility" of Fusarium wilt

The environment also plays an important role in the "visibility" of disease in the crop. In some seasons Fusarium wilt is highly visible because the incidence of wilted and dying plants is high. In other seasons, the incidence of plants showing external symptoms can be much lower. What remains unknown is whether the incidence of plants with external symptoms matches the actual incidence of disease in the crop.

Our investigations

In an attempt to understand more about the impact of environmental conditions on Fusarium wilt of cotton we followed the progress of disease in fields near Moree and Goondiwindi over the 2003/4 season. We counted the incidence of internal (vascular) and external (foliar) disease symptoms in 200 plants nine times throughout the season near Goondiwindi. In two separate experiments conducted near Moree we measured disease in cotton sown one month apart and disease in pre-irrigated versus watered-up cotton respectively.

Our results

Incidence of external symptoms did not match actual disease incidence

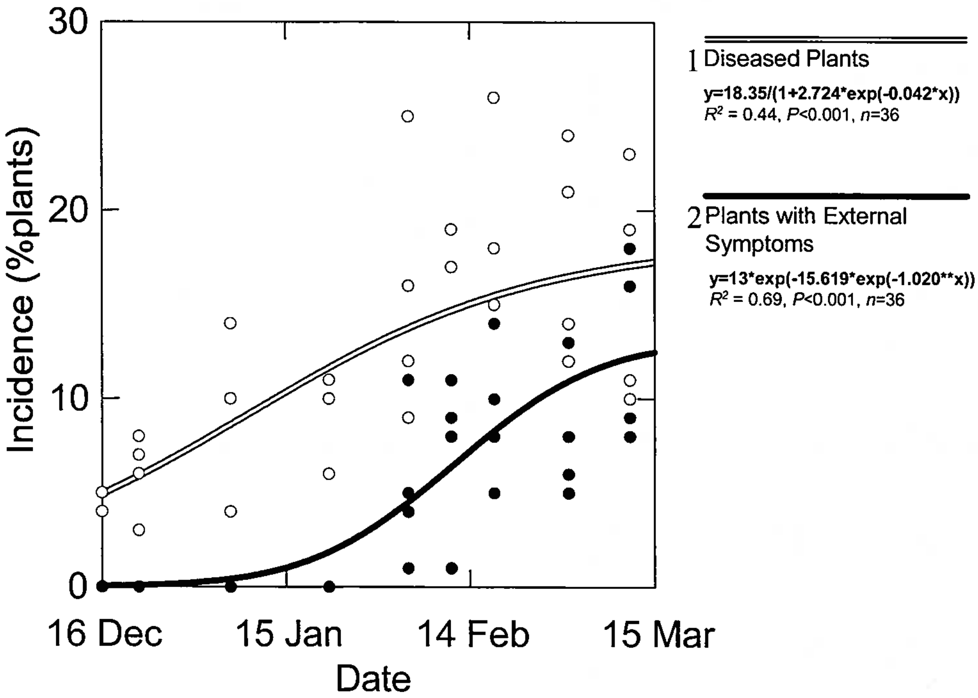

Figure 2. Actual disease incidence counted as plants with vascular discoloration (1) and diseased plants displaying external symptoms (2).

The "visibility" of disease never matched the actual incidence of disease (Figure 2). The actual incidence of disease was always higher than the incidence of plants displaying external symptoms. The "gap" of plants with internal but no external symptoms could represent recently infected plants, plants within which diseased had progressed more slowly, and/or plants with naturally higher levels of resistance. Interestingly, we did not see any external symptoms among diseased plants on the 22nd January, but when we returned on the 4th February approximately 5% of plants displayed external symptoms. We speculate that this may be related to the drop in soil temperature recorded between the 29th of January and the 4th of February caused possibly by irrigation on the 29th of January (data not shown). Further studies are needed to determine the factors contributing to the sudden appearance of external symptoms in future seasons.

Planting late reduced levels of disease and increased plant survival

Table 1. Results for planting date experiments 1 and 2 (see text).

	EXPERIMENT 1- Moree			EXPERIMENT 2- Moree		
	EARLY	LATE	Probability	EARLY	LATE	Probability
Planting Date	10-Oct	10-Nov		10-Oct	30-Oct	
Irrigation	Pre-irrigated	Pre-irrigated		Water-up	Pre-irrigated	
Plant Stand (pl./m)	7.5*	15.1*	p<0.001	7.4**	13.1***	p<0.001
BRR Severity (0-10) 5 WAS	7.6	2.2	P<0.001			
Bolls Per Metre 5.2.04	41	37	p=0.074			
Final 0's and 1's (pl./m)	4.8	12.5	p<0.001	2.8	7.1	p<0.001
Total Survival (%)	65	83	p=0.003	38	54	p=0.007
Module Weight (T)	13.7	13.6	N/A			
* 31DAS, **17DAS, ***15DAS				DAS: days after sowing		

In the first experiment, cotton planted on the 10th November had approximately twice the stand, almost ¼ the severity of Black Root Rot infection, almost three times the number of healthy plants at the end of the season and a survival rate 27% higher than cotton planted one month earlier (Table 1). Moreover, there was no difference in bolls per meter on the 5th of February and no difference in yield at the end of the season (Table 1). Thus, planting on the 10th of November substantially reduced disease whilst producing a yield that was no different to planting in early October.

In the second experiment, cotton that was pre-irrigated and planted late had almost twice the stand, more than twice the number of healthy plants at the end of the season and a survival rate 42% higher than cotton that was planted early and watered-up (Table 1).

So what does it all mean?

These experiments demonstrate that late planting of cotton can reduce the severity of Fusarium wilt and Black Root Rot. However, late planting may not always achieve results similar to those reported in this paper because environmental conditions will differ between seasons. Using a conventional variety we were able to avoid disease and achieve the same yield as cotton planted one month earlier. In the future, Bollgard™ varieties may enable growers to avoid disease and actually increase yields. We intend to investigate this possibility in future experiments.

The impact of planting late could not be separated from the impact of irrigation because unforseen rainfall forced a much later planting date of pre-irrigated cotton then we had originally anticipated. Thus, we cannot draw any conclusions as to the effect of irrigation on the severity of Fusarium wilt. The late planting date of the pre-irrigated cotton may explain the reduction in the severity of Fusarium wilt observed in this treatment.
We were able to substantially reduce the severity of Fusarium wilt at the end of the season by manipulating factors at the beginning of the season, suggesting that the most critical period for development of the disease occurs at the beginning of the season. The potential effectiveness of novel control strategies may be enhanced if they are designed to be applied during this period.

Furthermore, it has long been suggested that Fusarium wilt occurs in two waves, the first wave of disease occurring at the beginning of the season and the second later in the season. Our results could be interpreted in this way with stand loss at the beginning of the season representing the first wave and the sudden increase in external symptoms in February representing the second wave. However, it is probably erroneous to consider these two waves as distinct events. Rather, our results suggest that the two waves may be the result of one infection event at the beginning of the season. Whilst it is assumed that plants continue to become infected as the season progresses, our studies suggest that disease resulting from early season infection makes the most substantial contribution to disease observed at the end of the season.

A logical "next-step" for our research would be to investigate whether planting date and irrigation at the start of the season can affect the visibility of disease throughout the season. If differences in disease "visibility" are related to differences in yield then this question will be very important. At the very least, it is likely that high disease "visibility" is related to high levels of pathogen reproduction. We intend to combine our technique of observing internal and external symptoms throughout the season with the manipulation of planting date and irrigation at the start of the season in future experiments.

Late planting may be an excellent strategy for reducing the severity of Fusarium wilt and other soil-borne diseases of cotton in Australia. While we encourage growers to think about adopting this strategy, we reiterate that seasonal effects may negate its effectiveness. Repetition of these studies over the next few years under different environmental conditions and in different regions will provide a more accurate picture of the potential benefits of planting late and help us to clarify the real impact of pre-irrigation and watering up on disease. Disease management strategies cannot be holistic without considering the impact of the environment on disease severity. We believe that the modification of planting dates will play an important role in future integrated disease management strategies.

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