A wet summer followed by a wet winter, a recipe for severe take-all damage to cereal crops in cereal dominant rotations

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Abstract

Cereal on cereal crop sequences are becoming more common in cereal growing regions of Australia. This sequence choice is often made because cereal crops are deemed either most profitable or lowest risk. In addition, the dry seasons encountered from circa 2000 to 2009 in many wheat growing regions in Australia meant that disease problems, like those caused by take-all, declined. However, substantial rainfalls throughout Australian grain growing regions may re-ignite disease problems and the cereal on cereal crop sequence may become a costly crop sequence. We revisit a long term historical crop sequence experiment conducted in Kapunda in South Australia from 1983 to 1990 to determine how the disease incidence changes over time and determine what impact disease incidence, measured 6-8 weeks after sowing, has on wheat yield. In addition, we explore seasonal rainfall patterns to determine what conditions lead to a decrease in disease risk. Take-all incidence increased from 1984 to 1986, decreased to very low levels (< 10%) in 1987 and 1988, then increased again in 1989 before decreasing again in 1990. The decreases in incidence occurred in seasons where high summer rainfalls (Dec – March) (> 80mm) preceded the growing season. The increases in disease incidence occurred following a wet cool spring (Sept – November) (> 140mm) and comparatively dry summer. High levels of disease incidence did not necessarily affect crop yield. Crop yields declined linearly with increasing disease incidence in 3 years (1986, 1987 and 1988) out of the 8 surveyed. These three seasons had the highest summer rainfalls of the 8 surveyed. Different mechanisms appear to be acting on the crop in these seasons, as 1986 was quite wet, where disease free crops yielded 4.3 t/ha, while 1987 was dry, with disease free crops yielding 3.0 t/ha. Overall, if levels of disease incidence are moderate (> 25%) then crop yields may be reduced by 0.5 t/ha. This increases to around 1 t/ha if levels of disease incidence increase to 40% or more. Overall, the incidence of take-all and its impact on wheat yield were influenced by the rainfall pattern both in the preceding summer and during the spring within the crop.

Key Words

Take-all, Long term trends, climate, Crop sequences.

Introduction

Cereal on cereal rotations are increasingly being adopted by farmers throughout Australia and this could lead to an increase onset of soil borne disease such as take-all that is present to some extent in most Australian soils. However, the increase in disease incidence levels and the impact that diseases such as take-all have on cereal yield is variable and dependent on seasonal conditions (Roget and Rovira 1991, Kirkegaard *et al.* 2000). It is essential to understand and quantify the nature of the variation in disease impacts on cereal yield, as farmers may become complacent and unwittingly employ cereal dominant rotations without recognising the potential downside risk. If there have been sequences of seasons with below average long term rainfall or abnormally wet summers, then it is possible that the incidence levels of diseases like take-all will be low (Roget and Rovira 1991). Often, statewide distributions of incidence levels for take-all follow the rainfall isohyets (Yeates *et al.* 1986), where the incidence levels are higher in the wetter regions. Similarly, the run of seasons can result in either a buildup or decline in incidence levels. The build up in incidence levels can even occur in low rainfall districts and it is important that farmers are aware of how quickly diseases can build up or decline. A build up in incidence can reduce the chance of a cereal crop reaching its yield potential.

Historical experimental crop sequencing data from Kapunda in South Australia were reanalysed to explore how quickly incidence levels can change in a continuous wheat rotation. We also considered the seasonal conditions that might predispose a cereal crop to substantial yield loss when disease incidences are high.

Methods

Site locations and treatments

The experiment was conducted at Kapunda, South Australia from 1983 to 1990 on a red-brown earth soil. In the first year of trial establishment, continuous wheat (cultivar Spear) was sown following a volunteer pasture phase and was subjected to three different tillage treatments; conventional cultivation (cc), reduced tillage (rt) and direct drilled (dd). Each treatment was replicated 18 times. Therefore, in each year 54 plots of wheat were harvested. In addition, disease incidence was assessed 6 – 8 weeks after sowing (~ gs 30 - 40) where the roots from 20 to 25, wheat plants within each plot were scored for the incidence and severity of take–all.

In the following years (1985-87) a rotation component was included in the experiment where either pasture, lupins or wheat were grown prior to a following wheat crop. The entire experiment was repeated one year out of phase so that both the rotation phase and the wheat phase could be monitored each year. Each treatment was replicated 6 times and these data were also included in the analysis, and designated as part of the rotation trial. Wheat yields were measured at harvest and incidence levels were again measured at 6 – 8 weeks after sowing.

Statistical analysis

The 'asreml' library from the R (v2.12) statistical package was used to conduct a meta- analysis of these two trials. Initially the objective was to determine what impact take-all incidence had on crop yield in each of the 8 seasons and formally explore whether the effect of take-all incidence on crop yield varied from one season to the next. The data were analysed using a mixed model, where the year (categorical) and incidence (continuous) were fitted as main effects and as an interaction in the fixed model. In the random model treatment within year within the trial and block within year within trial was included in the random model. The random model accounted for the treatment and block effects within a year that were part of the original trial design. These were of no interest here and were included in the random model to improve the statistical fit of the data.

An equivalent statistical model was fitted to the log transform of incidence levels (LI). In this instance, the year and LI from the previous year were fitted to LI. This model was used to explore the effect the previous LI had on the current LI. Treatment within year and rep within year were again included in the random model to improve model fit. Data from the non-cereal rotations were excluded as disease incidence could not be assessed. Again, year and previous LI were fixed.

Results and Discussions

Rainfall Patterns and Crop Yields

Rainfall in all seasons was remarkably good, where growing season rainfall (April – November) averaged 403mm and ranged from a low of 367mm in 1984 to 477 mm in 1986 (table 1). Severe post anthesis moisture stress would have been unlikely in all seasons, although the distribution of rainfall within the season did vary. In the 1986/1987 summer, 75mm of rainfall was recorded, almost double the trial average of 41mm. The 1987/1988 summer was the second wettest, with 55mm of rainfall. There was also a particularly wet spring (153mm) in 1988.

Table 1. Growing Season and Annual Rainfall at Kapunda over the trial period

Rainfall(mm)	1983	1984	1985	1986	1987	1988	1989	1990	Mean
Apr-Nov	409	367	394	477	406	405	396	373	403
Annual	570	448	498	543	497	543	473	430	500

Trends in disease incidence under continuous wheat

Take-all disease incidence (log transformed) in the previous year did not influence disease incidence levels in the following year. The statistical model was altered, where year was fitted to incidence levels to determine the temporal trend in the data. In this continuous wheat system, incidence levels remained high from 1983 to 1986. Levels declined in 1987 and 1988, but increased in 1989 before again declining in 1990 (Figure 1). The increase in incidence levels in 1989 followed a wet spring in 1988 (153mm) and the second driest summer in the experiment (22mm), while the decrease in incidence in 1987 occurred after the wettest summer.

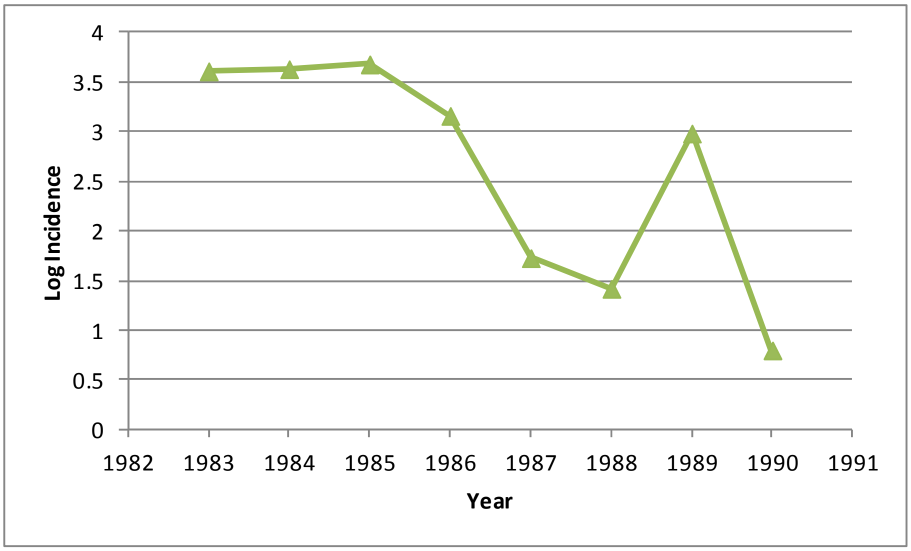

Figure 1. Trends in the log of incidence levels for take-all from 1983 to 1990

Effect of take-all incidence on wheat yield

As expected, wheat yields varied markedly from season to season. High yielding seasons occurred in 1984, 1986 and 1988, where crops yielded 3.6, 4.3 and 3.4 t/ha respectively. In contrast, 1985 (2.16 t/ha) and 1990 (2.08t/ha) were low yielding. The influence of incidence level on wheat yield varied considerably from one year to the next. In 1986,1987 and 1988, significant yield loss occurred when incidence was present where an incidence level of 25% reduced crop yield by at least 0.5 t/ha. This yield loss increased to at least 0.9 t/ha when incidences levels rose to 40%. In the remaining seasons, incidence did not statistically reduce crop yield and the relationship between incidence level and wheat yield was not statistically different from zero. Therefore the incidence yield relationship varied with season (Figure 2).

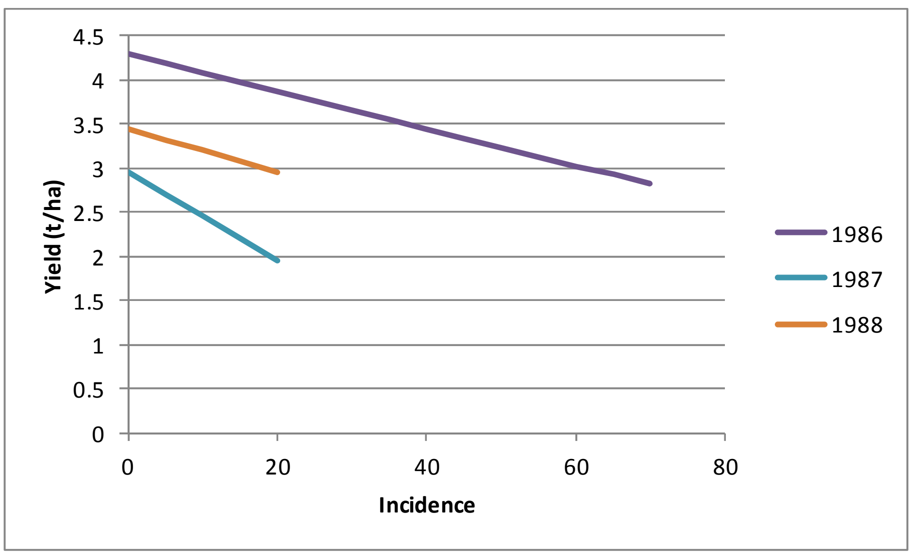

Figure 2. Relationship between grain yield and take-all disease incidence in 1986, 1987 and 1988. In each year, the line does not extend beyond the maximum level of take-all incidence recorded in wheat plots in that season. The equations of the lines are, 1986 : yield(t/ha) = 4.28 – 0.021(incidence), 1987: yield(t/ha) = 2.96 – 0.050(incidence), 1988: yield(t/ha) = 3.45 – 0.025(incidence).

Understanding the importance of climate on disease yield relationships

Disease incidence reduced wheat yield in 1986, 1987 and 1988. The 1986 growing season was characterised by a wet (216mm) start to the growing season and an equally wet spring (199mm). The crop would never have suffered moisture stress and conditions could only be described as perfect, unless the crop was exposed to waterlogging. Crop yields reached 4.3/tha. Under these climatic conditions, incidence levels in some plots were at 70% and these crops yielded just 2.8 t/ha. It is possible that in the favourable conditions root growth was compromised to such an extent that crop water use was compromised and crops with high incidence levels were unable to take advantage of the favourable conditions.

In 1987, winter rainfalls were good (193mm) but spring rainfall was the lowest (86mm). Crop yields were 2. 95 t/ha, and it is possible that crops experienced moisture late in the growing season. Even though incidence levels were low in 1987 (< 20 %), the take-all significantly compromised crop yield where a take-all incidence of 10% reduced crop yield by 0.5 t/ha. The good winter rainfalls in 1987 would have ensured the crop was growing vigorously, and the yield penalty may have occurred because a diseased crop would have been unable to exploit soil moisture deep in the profile. 1987 was unique at this site, as it had the lowest spring rainfall of all the seasons monitored and there was only one other season with comparable rainfall (1990).

There were similarities between 1988 and 1986 as good winter rainfalls (193 mm) were followed by good spring rainfalls (153mm). The climatic conditions may have been favourable for disease buildup late in the season that then compromised the crops ability to extract the extra moisture available. However, without dedicated soil moisture equipment, it is difficult to determine exactly how yields were suppressed. Perhaps surprisingly, the effect incidence levels had on wheat yield was negatively correlated with the amount of rain that fell in the previous summer (December, January and February) ($r = -0.74$, $p > 0.05$). This could be because the summers of 1986, 1987 and 1988 were the three wettest encountered during the trial period. The impact that take-all incidence would have on wheat yield in these seasons is given in Figure 2. Given this relationship, it is likely that the summer rainfalls increased subsoil moisture. Even though take-all incidence in these seasons was generally low (Figure 1), this summer rainfall may have increased stored soil moisture and helped to lift crop yields in the following season. Even though incidence levels were low in these seasons, it is possible that these incidence levels were sufficient to limit the crops ability to access soil moisture at depth. In these seasons, with low spring rainfalls, the crop may have needed this deep stored soil moisture to yield. This could have contributed more than anything else to the large coefficients detected in those years.

Conclusion

Take-all incidences varied dramatically from season to season in a long term continuous wheat experiment conducted at Kapunda, South Australia. In addition, the take-all incidence was not influenced by the incidence of take-all in the previous year and was reduced by summer rainfall. Take-all disease incidence had varying impacts on wheat crop yield. In 5 of the 8 seasons monitored, the effect on cereal crop yields was negligible. However in the remaining three years, yield penalties of more than 0.5 t/ha were common. Further soil water monitoring experiments are required, but take-all could be limiting the crops ability to draw on subsoil moisture and it predisposes the crop to post anthesis moisture stress. The unpredictable nature of the buildup and decline of take-all, combined with the possibility that it may or may not influence cereal crop yields may mean farmers are willing to take a risk with cereal on cereal rotations that at some point will suffer a substantial yield penalty.

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