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Combining agronomy, variety and chemistry to maintain control of septoria tritici in wheat

Morgan C.[1], Wright P.[1] Blake J.[1], Corkley, I.[2], Knight S.[3], and Burnett F.[4]

[1] ADAS Rosemaund, Preston Wynne, Hereford, HR1 3PG.

[2]ADAS Wolverhampton, Titan 1 Offices, Coxwell Avenue, Wolverhampton, WV10 9RT.

[3] NIAB, 93 Lawrence Weaver Road, Cambridge, CB3 0LE.

[4] SRUC, Peter Wilson Building, West Mains Road, Edinburgh, EH9 3JG.

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CONTENTS

1. Abstract

Septoria leaf blotch (*Zymoseptoria tritici*) is one of the most damaging diseases on winter wheat in the UK. It is estimated to cause annual yield losses worth between £110–£220m, despite fungicide applications (Fones et al. 2015). The chemical control of this pathogen is becoming increasingly difficult because of the loss of active ingredients, tighter legislation on pesticide use and the development of fungicide resistance. As a result, the control of septoria can sometimes be poor, despite a significant spend on fungicides. The use of cultural control measures, as part of an integrated pest management (IPM) strategy, is important to maintain control of this disease.

This project investigated the impact of four factors on the severity of septoria and final yields: sowing date, seed rate, variety and fungicide. The work involved 25 field trials, conducted across five harvest years (2016–20). The project aimed to determine the value of agronomic factors and establish the extent to which fungicide use can be adjusted when using cultural control strategies.

Earlier sowings consistently resulted in higher disease severity during the main yield-forming period than later sowings. This is most likely due to crops being exposed to spores earlier in the season. Variety and fungicide also had a significant effect on septoria severity, with a clear interaction between the two. The yield response to fungicides was much smaller in more resistant varieties, compared to susceptible varieties. Higher seed rates, and, therefore, thicker crops, can lead to greater disease severity. However, the effect was small and inconsistent across trials.

It is concluded that growers should tailor their fungicide strategy to variety and sowing date to better optimise the use of fungicides. By sowing varieties with stronger disease resistance later in the autumn, there may be considerable scope to reduce the risk of a damaging septoria epidemic – enabling the use of lower fungicide inputs. This report includes a measure of the extent to which varietal susceptibility to septoria may be increased or decreased with earlier or later sowing, respectively.

2. Introduction

Septoria is considered the most damaging foliar disease in UK winter wheat crops. The lower leaves of winter sown crops are normally infected by the spread of airborne ascospores throughout winter and early spring. Once a plant is infected, fungal spores (pycnidiospores) are released when the plants are wet and spread by rain-splash to the upper leaves as the crop grows. Symptoms are expressed as necrotic (dead tissue) lesions on the surface of the leaf, reducing the area available for photosynthesis. As a result, septoria causes significant yield losses every year, and it can be up to 50% in the most severely affected crops (Eyal et al. 1987, AHDB 2020a).

Management of septoria in wheat currently relies heavily on control with fungicides. At the time of writing two groups of fungicides, the azoles and the succinate de-hydrogenase inhibitors (SDHI's), form the basis of most programmes for the control of septoria in UK cereals. However, there are significant declines in sensitivity of both groups, due to the detection of moderately resistant isolates in the UK population (Blake et al. 2018, Jørgensen et al. 2020, Rehfus et al. 2018). Additionally, actives are threatened by the introduction of new legislation (Hillocks 2012). A notable recent example being the ban in the UK of multisite fungicide, chlorothalonil, in 2020. Although new chemistry may be available in the short term, the succession of new actives is likely to reduce, as chemical manufacturers are increasingly facing technical and political difficulties in developing new actives and registering new products. Therefore, just as for black-grass, it is essential that growers utilise cultural methods for managing septoria as part of an integrated pest management approach.

Several factors such as variety, sowing date, seed rate and nitrogen timing, have been shown to affect the development of septoria epidemics in wheat (Gladders et al. 2001, Fones et al. 2015, Ansar et. al. 2010, Tompkins et. al. 1993). These factors either delay the onset of the epidemic, reduce the infection efficiency, extend the latent period of infection, or reduce the rate of sporulation. Historically, popular varieties have had only moderate levels of resistance (i.e AHDB Recommeded list (RL) rating of 5 to 6 out of 9) against this pathogen, which has increased reliance on fungicides. Though new varieties with higher resistance (i.e RL rating greater than 7) have regularly entered the market, the benefit is often offset by poorer performance in other agronomic factors, such as lower yield potential and specific weight. Since the 1990s there had been a trend towards earlier sowing, non-inversion tillage and lower seed rates for wheat, but more recently, in some parts of the UK, delayed drilling and higher seed rates have been used as cultural control measures to combat resistant black-grass. All these changes may affect disease control requirements. However, the relative importance of these factors, how they interact (and hence how they are best combined within integrated control strategies) and the extent to which they may alter the fungicide requirements of the crop, is poorly quantified.

This report looks at the value of cultural control measures as part of an integrated disease management programme, using data collected from 25 sites (UK and Ireland) across 5 growing seasons (2016-2020). Sowing date, seed rate, and variety choice were investigated for their potential to reduce the intensity of fungicide required, whilst minimising yield losses to septoria and maximising financial return for growers. It aims to provide reassurance on the scenarios where septoria risk is reduced and there is scope to reduce fungicide inputs.

3. Materials and methods

3.1. Field trials

3.1.1. Site selection and establishment

The experiments were conducted over five harvest years (2016 – 2020) across the UK and Ireland to test how agronomy, variety and chemistry effect the control of septoria. These sites were chosen to give a good range of high to low disease pressure in which to test the different agronomic factors. For years 2016 – 2018, sowing date, seed rate, variety and fungicide programme were varied at each site. Seed rate was not included for years 2019 and 2020 (Table 1).

Each of the trial sites had at least a one year break from cereals to minimise the risk of take-all increasing variability across the trial plots or interfering with fungicide yield responses. The plot size in each trial was a minimum of 20m^2, and good farm practice was followed for all inputs (with the exception of fungicides) to ensure, as far as possible, that the trials were not affected by factors other than septoria pressure.

In 2019 and 2020 the site at ADAS Rosemaund was irrigated to increase disease pressure. Irrigation was applied once a week from mid-May onwards, unless there were two rainfall events with greater than 5mm in the prior week (under these circumstances supplementary irrigation was considered unnecessary). At each irrigation event approximately 5mm of water was applied evenly across all plots. All sites relied on natural disease infection.

Table 1: Trial site numbers, locations, harvest years and agronomic factors investigated

Site Number	Host	Location	Harvest Year	Agronomic Factors Investigated			
				Sowing Date	Seed Rate	Variety	Fungicide Program
1	ADAS	Rosemaund, Herefordshire	2016	✓	✓	✓	✓
2	ADAS	Terrington, Norfolk	2016	✓	✓	✓	✓
3	NIAB	Sutton Scotney, Hampshire	2016	✓	✓	✓	✓
4	SRUC	East Saltoun, East Lothian	2016	✓	✓	✓	✓
5	Teagasc	Carlow, Ireland	2016	✓	✓	✓	✓
6	UCD	Lyons, Co. Kildare, Ireland	2016	✓	✓	✓	✓
7	ADAS	Rosemaund, Herefordshire	2017	✓	✓	✓	✓
8	ADAS	Terrington, Norfolk	2017	✓	✓	✓	✓
9	NIAB	Sutton Scotney, Hampshire	2017	✓	✓	✓	✓
10	SRUC	East Saltoun, East Lothian	2017	✓	✓	✓	✓
11	Teagasc	Carlow, Ireland	2017	✓	✓	✓	✓
12	UCD	Lyons, Co. Kildare, Ireland	2017	✓	✓	✓	✓
13	ADAS	Rosemaund, Herefordshire	2018	✓	✓	✓	✓
14	ADAS	Terrington, Norfolk	2018	✓	✓	✓	✓
15	NIAB	Sutton Scotney, Hampshire	2018	✓	✓	✓	✓
16	SRUC	East Saltoun, East Lothian	2018	✓	✓	✓	✓
17	Teagasc	Carlow, Ireland	2018	✓	✓	✓	✓
18	UCD	Lyons, Co. Kildare, Ireland	2018	✓	✓	✓	✓
19	ADAS	Rosemaund, Herefordshire	2019	✓	×	✓	✓
20	NIAB	Sutton Scotney, Hampshire	2019	✓	×	✓	✓
21	SRUC	East Saltoun, East Lothian	2019	✓	×	✓	✓
22	Teagasc	Carlow, Ireland	2019	✓	×	✓	✓
23	ADAS	Rosemaund, Herefordshire	2020	×	×	✓	✓
24	NIAB	Sutton Scotney, Hampshire	2020	✓	×	✓	✓
25	SRUC	East Saltoun, East Lothian	2020	✓	×	✓	✓

3.1.2. Experiment design

A randomised, split plot design incorporating standard randomisation of treatments within each replication was used. The different sowing dates were sown in split plots, and seed rate, variety and fungicide randomised within. Sites 1 – 18 incorporated 48 treatments with three replications. Sites 19 – 25 incorporated 24 treatments with three replications.

3.1.3. Sowing date

Two sowing windows were used, broadly referred to as ‘early’ and ‘late’, early sowing targeted mid-September and late sowing mid-October. Due to unsuitable ground conditions at the target timing at some sites in some years, actual sowing dates range for the ‘early’ from the 3rd September to

the 7th October, averaging the 22nd September, and 7th October to the 6th November, averaging 20th October for the 'late'.

3.1.4. Seed rate

For sites 1 – 18, two seed rates were used, broadly referred to as 'high' and 'low'. Seed rates were determined in order to establish a target plant population. As establishment is affected by time of sowing, seed rates were calculated prior to sowing using the equation:

Seed rate (kg/ha) = (Target plant population (m^2) x TGW (g)) / (Establishment (%))

The target plant populations used were:

- Low seed rate, early sown – 80 plants/m^2
- High seed rate, early sown – 160 plants/m^2
- Low seed rate, late sown – 160 plants/m^2
- High seed rate, late sown – 240 plants/m^2

3.1.5. Variety

Three varieties were sown at each site with differing susceptibilities to septoria. These are referred to as 'susceptible', 'moderately susceptible' and 'moderately resistant'. Varieties were chosen and their resistance scores recorded based on the AHDB Recommended List that would have been available to growers at the time of sowing (Table 2). For example, for the 2020 harvest season, the 2019/20 Recommended List was used. Varieties were also chosen for their good resistance to other, non-target diseases. The varieties used were changed during the project to reflect choices relevant to growers and the changing recommendations.

Table 2: Varieties used at each site and their resistance rating to septoria

Site	Susceptible Variety	Septoria Rating	Intermediate Variety	Septoria Rating	Moderately Resistant Variety	Septoria Rating
UK 2016	Santiago	4.4	JB Diego	5.3	Revelation	6.4
Ireland 2016	Cordiale	4.8	JB Diego	5.3	Rockefellar	*
UK 2017	Santiago	4.4	JB Diego	5.3	Revelation	6.3
Ireland 2017	Cordiale	4.8	JB Diego	5.3	Rockefellar	*
UK 2018	Santiago	4.3	JB Diego	5.2	Revelation	6.4
Ireland 2018	Cordiale	4.8	JB Diego	5.2	Rockefellar	*
UK 2019	Santiago	4.3	Hardwicke	5.8	Graham	6.9
Ireland 2019	JB Diego	5.3	Costello**	6.4	Bennington **	6.4
UK 2020	Elation	4.3	Elicit	6.0	Firefly	7.0

* A resistance score was not available for this variety.

** These varieties were awarded the same resistance ratings to septoria in the AHDB Recommended List 2018-2019 (UK data). In the equivalent recommended list from the Department of Agriculture, Food and the Marine (Ireland data), Costello has a resistance score of 5 and Bennington a score of 6.

3.1.6. Fungicide treatments

Four levels of fungicide input were tested. These were referred to as 'low', 'medium' and 'high' input programmes, with an untreated that received no fungicides for the control of septoria (azoxystrobin was applied alone at T0 for the control of rusts for experimental purposes. Note that use alone is not appropriate for commercial practice). Products were carefully selected so that higher input programmes involved additions to the lower input strategies. This minimised the risk of changes in product or mode of action activity from invalidating the results. Products used were substituted, when necessary, to reflect changes in product efficacy and regulation (Table 3). Where this occurred, due consideration was given to ensure new programmes would provide similar levels of efficacy, and additive inclusions between low, medium and high programmes, compared to preceding strategies.

Fungicides were applied using handheld plot spraying equipment, with 200 – 300 kpa of pressure to produce a medium spray quality. Sprays were applied at a rate of 200 l/ha.

Table 3: Fungicide programmes, rate presented in l/ha. CTL = Chlorothalonil. ***Note that Amistar (Azoxystrobin) should always be used in a mixture with another product when applied commercially.***

Year	Treatment	T0 (GS30)	T1 (GS32)	T2 (GS39)	T3 (GS61-65)
2016 to 2018	Untreated	Amistar 0.5	Untreated	Untreated	Untreated
	Low	Amistar Opti 1.0	CTL 1.0	CTL 1.0	Folicur 0.75
	Medium	Amistar Opti 1.0	Brutus 1.5 + CTL 1.0	Brutus 2.25 + CTL 1.5	Folicur 0.75
	High	Amistar Opti 1.0	Brutus 1.5 + CTL 1.0 + Imtrex 1.0	Brutus 2.25 + CTL 1.5 + Imtrex 1.5	Folicur 0.75
2019	Untreated	Amistar 0.5	Untreated	Untreated	Untreated
	Low	Amistar Opti 1.0	CTL 1.0	CTL 1.0	Folicur 0.75
	Medium	Amistar Opti 1.0	Brutus 1.5 + CTL 1.0	Brutus 2.25 + CTL 1.5	Folicur 0.75
	High	Amistar Opti 1.0	Brutus 1.5 + CTL 1.0 + Imtrex 1.5	Brutus 2.25 + CTL 1.5 + Imtrex 2.0	Folicur 0.75
2020	Untreated	Amistar 0.5	Untreated	Untreated	Untreated
	Low	Amistar 0.5	Sunorg Pro 0.5 + Phoenix 1.0	Sunorg Pro 0.6 + Phoenix 1.0	Folicur 0.75
	Medium	Amistar 0.5	Librax 0.8 + Phoenix 1.0	Librax 1.0 + Phoenix 1.5	Folicur 0.75
	High	Amistar 0.5	Revystar XE 1.0 + Phoenix 1.0	Revystar XE 1.25 + Phoenix 1.5	Folicur 0.75

3.1.7. Assessments

Assessments of foliar disease and green leaf area

Foliar disease and green leaf area assessments were carried out at T2 + 3-4 weeks and at T2 + 6-8 weeks on all plots. Ten tillers were assessed per plot. Tillers were randomly selected and assessed by estimating the percentage of green area and the percentage of each leaf affected by disease (including any necrosis and chlorosis associated with the disease).

Lodging

Plots were assessed for lodging prior to harvest. The percent area affected was recorded if lodging was present.

Yield and grain quality

All plots were harvested using a plot combine. Grain samples were taken to determine moisture content and for specific weight assessment. Yields were calculated at 85% dry matter. Specific weight of grain was measured for each plot and adjusted to 85% dry matter.

3.2. Weather data

Daily minimum and maximum air temperatures and total rainfall were recorded at each trial site.

3.3. Data handling

Disease, green leaf area, yield and grain quality data were collected manually or directly onto portable computers. All data were transferred to Microsoft Excel worksheets after collection.

3.4. Analysis

3.4.1. Individual site and season analysis

In all trials, disease, yield, and grain quality were summarised by analysis of variance. Data were examined and a small number of individual plot values excluded where justified. For example, where another non-target disease was recorded at greater than 10% severity on that leaf layer, septoria data was excluded. Yield and specific weight data were also excluded in plots where crop establishment was poor creating variable data.

Each season, results from all sites were combined to provide an across site mean for disease, yield and specific weight and analysed using analysis of variance. Site was included as a factor to show whether the effect was consistent across all sites. So that disease pressure at each site could be compared, the same leaf was analysed, leaf 3 for the first assessment and leaf 2 for the second assessment. These leaf layers were chosen as in most cases they had sufficient levels of disease to show treatment differences and had not yet senesced. This approach was taken in preference to averaging across several leaf layers which tended to dilute both the disease pressure and differences between treatments.

3.4.2. Combining results from different sites and seasons

An analysis across all sites and seasons was also completed, and sites were additionally analysed in groups by disease pressure. When analysing sites across years the data from the high seed rates was used for sites 1 to 18 to create a balanced design.

3.4.3. Effect of weather and severity on yield response to fungicide application

Several studies have shown a correlation between weather patterns and disease severity (Pietravalle et al. 2003, te Beest et al. 2009, Gladders et al. 2001). To explain the level of disease experienced at each site, a number of weather variables, that have been identified as important factors in disease severity models, were investigated with this data set (Table 4). As rainfall during the spring and summer is known to be a key driver of septoria severity, total monthly rainfall for the months of March, April, May and June were also included. For each site, the weather data was summarised for each of the weather windows and correlated with the back transformed, logit average of disease severity on leaves 1 and 2 at T2 + 6-8 weeks for the early sown, untreated susceptible variety.

The likely yield losses due to disease severity can be estimated (King et al. 1983, Cook et al. 1991, Milne et al., 2007, van den Bosch et al. 2020). Therefore, disease forecasting based on weather patterns could be used by growers as a guide to the yield response expected from fungicide applications, if disease prediction is sufficiently accurate (te Beest et al. 2013). To understand if sowing date (early/late) and cultivar type (high/medium/low disease resistance) affect the relationship of weather patterns with the yield response from fungicide application, the maximum yield response for each cultivar type and sowing date combination was calculated as the difference in mean yield between untreated plots and plots treated with the highest fungicide input, and correlated against each of several weather variables (Table 4). In addition, yield response to fungicide treatment at each site block was correlated with septoria severity data from untreated plots (average logit severity on the top two leaves 6-8 weeks after T2) for each cultivar type, sowing date and fungicide rate combination. Sites/blocks missing untreated severity or yield data were excluded from this analysis by necessity.

Table 4: Weather windows tested to check for correlations with disease severity and yield response across the sites. The time period each window represents is shown in brackets.

Weather Window	**Reference**
Number of days with rain greater than 9mm 90 days before GS75 for 37 days (01/04 – 08/05).	(Pietravalle et al. 2003)
Daily rain above 3mm accumulated 80 days before GS 31 e.g. If daily rainfall is 5mm, 2mm, 5mm and then 10mm over a 4-day period this would contribute 2mm, 0mm, 2mm, 7mm to the accumulations which would be 11mm in total. (11/02 – 30/04).	(te Beest et al. 2009)
Number of high-risk *Septoria* periods in May (consists of either a single day when total rainfall is greater than 10mm or up to 3 consecutive days with at least 1mm and a period total of 10mm).	(Gladders et al. 2001)
Number of high-risk *Septoria* periods in June (consists of either a single day when total rainfall is greater than 10mm or up to 3 consecutive days with at least 1mm and a period total of 10mm).	(Gladders et al. 2001)
Accumulated minimum temp with a 0 degree C base in the 50 day period starting from 120 days preceding GS31 (01/01 – 20/02).	(te Beest et al. 2009)
Number of days with night time temperature ≤-2 degrees C in November (01/11 – 20/11).	(Gladders et al. 2001)
Total Rainfall in March	
Total Rainfall in April	
Total Rainfall in May	
Total Rainfall in June	

3.4.4. Adjusting the resistance rating by sowing date

To measure the impact of sowing date on disease progress the disease differences observed between sowing dates, were compared using the methodology used in the ADHB Recommended List (RL) to determine resistance ratings based on disease differences between varieties. The AHDB Recommended Lists include varietal disease ratings using a scale from 1 (least resistant to disease) to 9 (most resistant to disease) (AHDB 2021), based on the average levels of disease observed on each variety in trials held across multiple locations. The sowing dates of the winter wheat Recommended List trials from 2017 to 2020 average approximately 7th October and span the average 'early' and 'late' sowing dates used in this project (22nd September and 20th October respectively). Recommended List resistance ratings therefore provide an indication of the average level of disease expected, but early or late sowing could change the effective resistance rating of varieties relative to this average.

To calculate the effect of sowing date on the effective resistance rating to septoria, a regression analysis of the average logit septoria severity on untreated plots on the top two leaves 6-8 weeks after T2, at each site in each year for early and late sowing dates, was carried out in Genstat v. 18 (VSNI), for each of the three levels of septoria resistance tested in each trial: susceptible varieties with resistance ratings ranging from 4.3 to 5.3, moderately susceptible varieties with resistance ratings ranging from 5.2 to 6.4, and moderately resistant varieties with resistance ratings ranging

from 6 to 7 (the lower end of this range corresponding to trials that also used the lower end of the range for moderately susceptible varieties). Data was excluded for any given variety at sites which did not have reliable disease severity data for the early and late sowing dates, resulting in a total of 19 sites being included in this analysis. A statistical comparison of separate regression lines with different slope and intercepts fitted for each level of resistance, parallel regression lines with the same slope but different intercepts, and a single regression line for all three resistance levels was carried out. In addition, the difference between average logit severity in early-sown and late-sown crops was plotted against the numeric resistance rating value, to check if the average difference varied with resistance rating.

To calculate adjusted septoria resistance ratings, it was assumed that the change in average logit severity between early and late sown crops was distributed evenly over time, such that the logit severity halfway between the values of logit severity for the early and late sown crops was assumed to be comparable with the average values used to calculate the published resistance ratings. For the observed range of early-sown logit severity values, the fitted regression equation was used to calculate the corresponding average predicted logit severity for late-sown crops, and the value mid-way between the early-sown and late-sown logit severity for comparison to Recommended List resistance ratings. The logit severity values were back-transformed to severity (%), then log-transformed using the formula y = log (severity + 1). The log severity was used to calculate the adjusted resistance rating for early and late sown crops from the regression line between log severity and AHDB resistance rating (Figure 1).

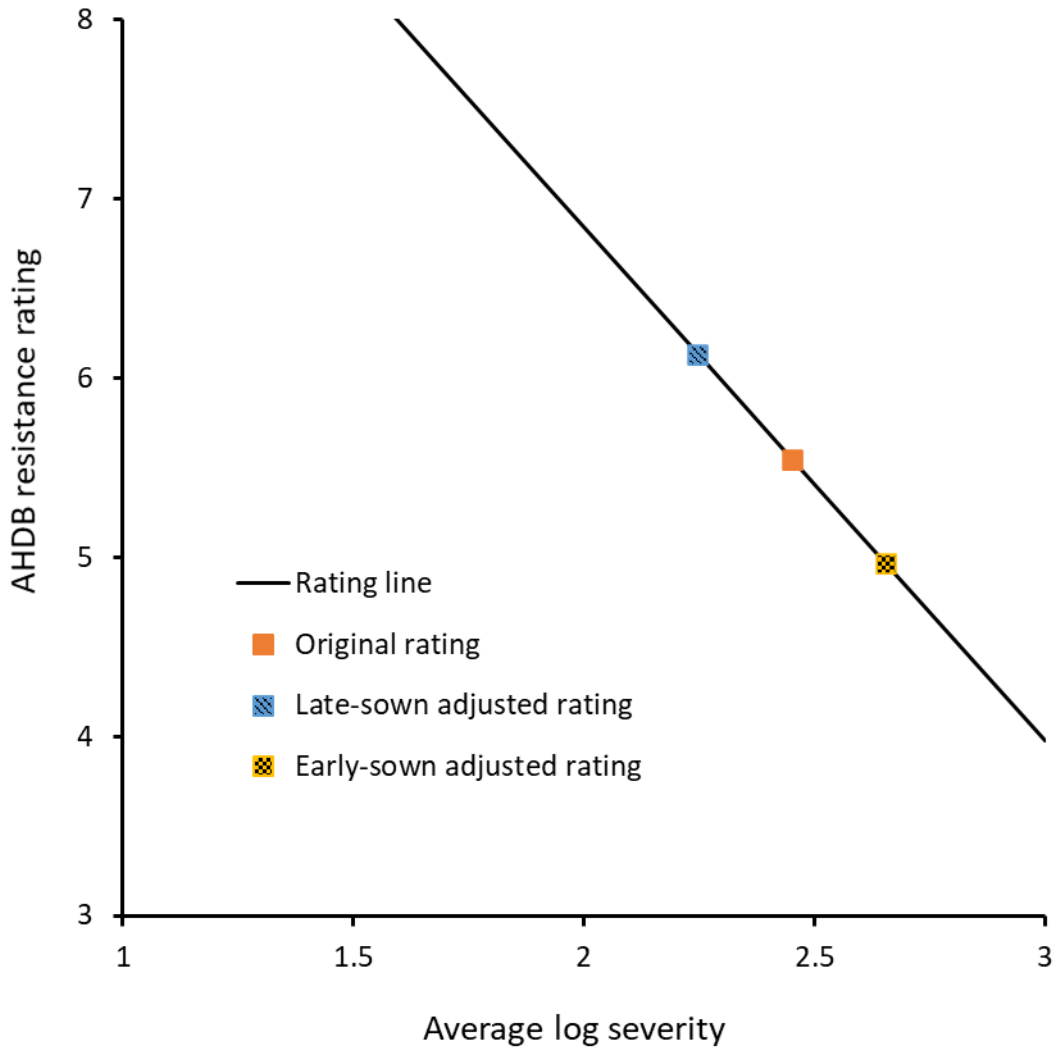

Figure 1: Example of method used to calculate adjusted septoria resistance ratings. The solid black line shows the rating line used to calculate the resistance rating based on the average log severity. For each given value of early-sown severity, the corresponding predicted values of late-sown and mid-way (original rating) were calculated, and the resistance rating corresponding to all three values predicted using the rating line.

4. Results

4.1. Effect of weather and severity on yield response to fungicide application

There were no significant correlations between any of the selected weather variables (Table 4) with either disease severity or the yield response from fungicides for any of the sowing date and cultivar combinations. This suggests there were not enough sites within this dataset that share a consistent weather factor influencing disease levels.

When looking at the rainfall patterns over the last 5 years this result is not surprising (Figure 2, Figure 3). In March, the MET office anomaly maps show that there is some variation in the rainfall across the 5 years, with 2018 being a particularly wet year and 2020 particularly dry. However, rainfall in March may be too early to strongly influence final disease pressure. Rainfall in April also showed some variation across seasons. However, 3 seasons (2017, 2019 and 2020) received

below average rainfall. 2016 was average and 2018 slightly higher than average. In May, all 5 seasons were very similar, receiving average or below average rainfall. May would be expected to be the most influential month as rainfall during this period splashes septoria spores up the canopy onto the top three, yield forming leaves. Rainfall in June shows the most variation, with above average rainfall received in the South in 2016 and 2019, the North in 2017 and the west in 2020. In comparison, 2018 was below average for most of the UK. However, rainfall in June can have a limited impact on final disease levels as septoria spores take approximately 20 days from landing on a leaf to producing symptoms. Therefore, any rainfall from mid-June onwards would not cause symptoms until early July, by which time the crop is starting to senesce, especially on lighter land / in England. Therefore, as May has been very similar over the course of this project our sites have been influenced by either early rainfall in March and April or late rainfall in June and so there is no common trend throughout.

There was weak correlation between septoria logit severity on untreated plots and fungicide yield response (Figure 4, Figure 5, Figure 6). The correlation was stronger for early sown crops (R^2 range 0.10 to 0.38) than late sown crops for which there was no correlation for most fungicide/cultivar combinations (R^2 range 0.01 to 0.20). For relatively susceptible and intermediate cultivars, but not for resistant cultivars, the correlation for early sown crops between severity and yield response was strongest for the high fungicide regime. The average yield response to fungicides was higher for early sown crops than late sown crops.

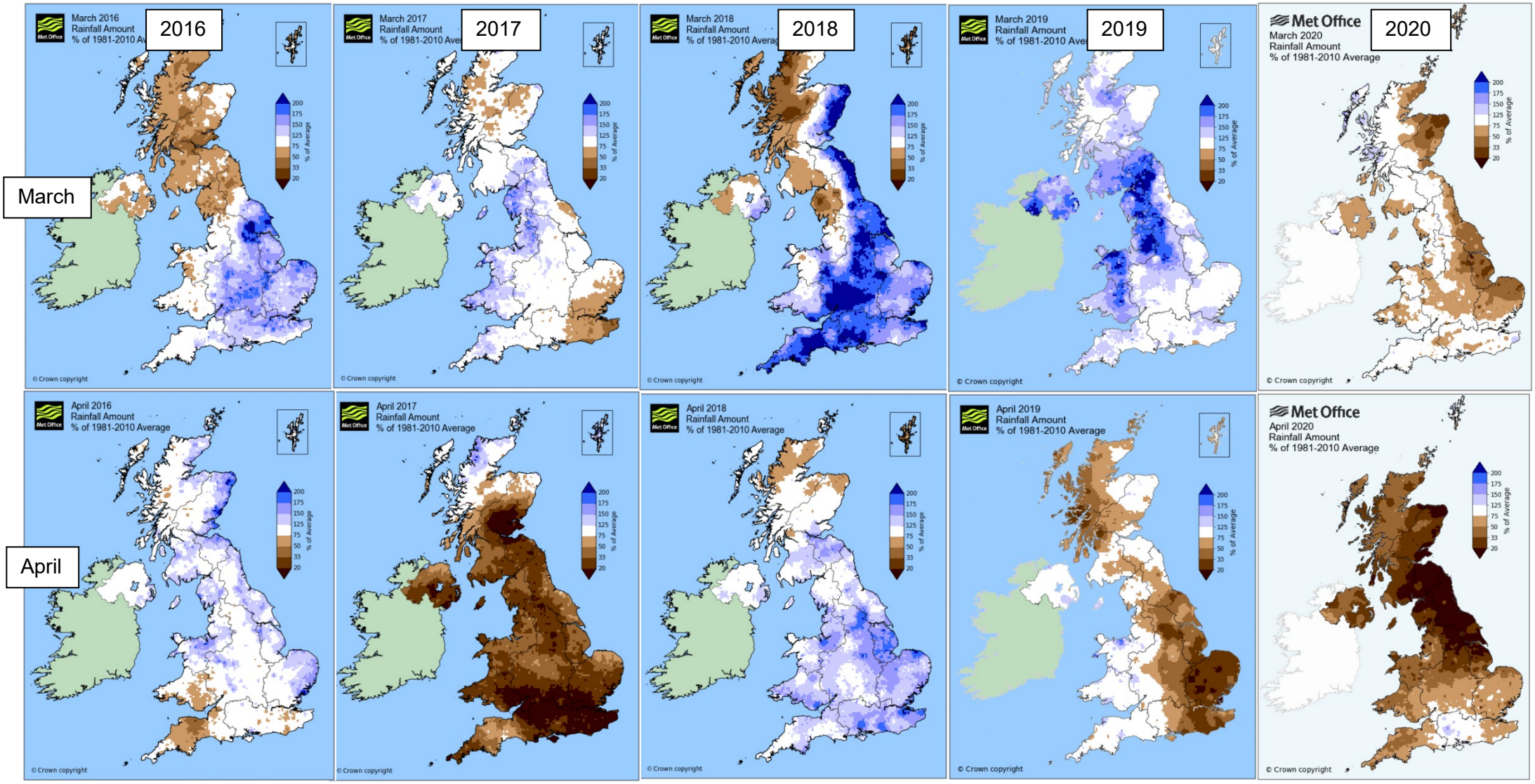

Figure 2: MET Office monthly anomaly maps showing rainfall in March and April for 2016 to 2020 as a percentage of the 1981 to 2010 average. Brown shows below average rainfall, white average and blue above average (MET Office, UK Actual and Anomaly Maps 2021b).

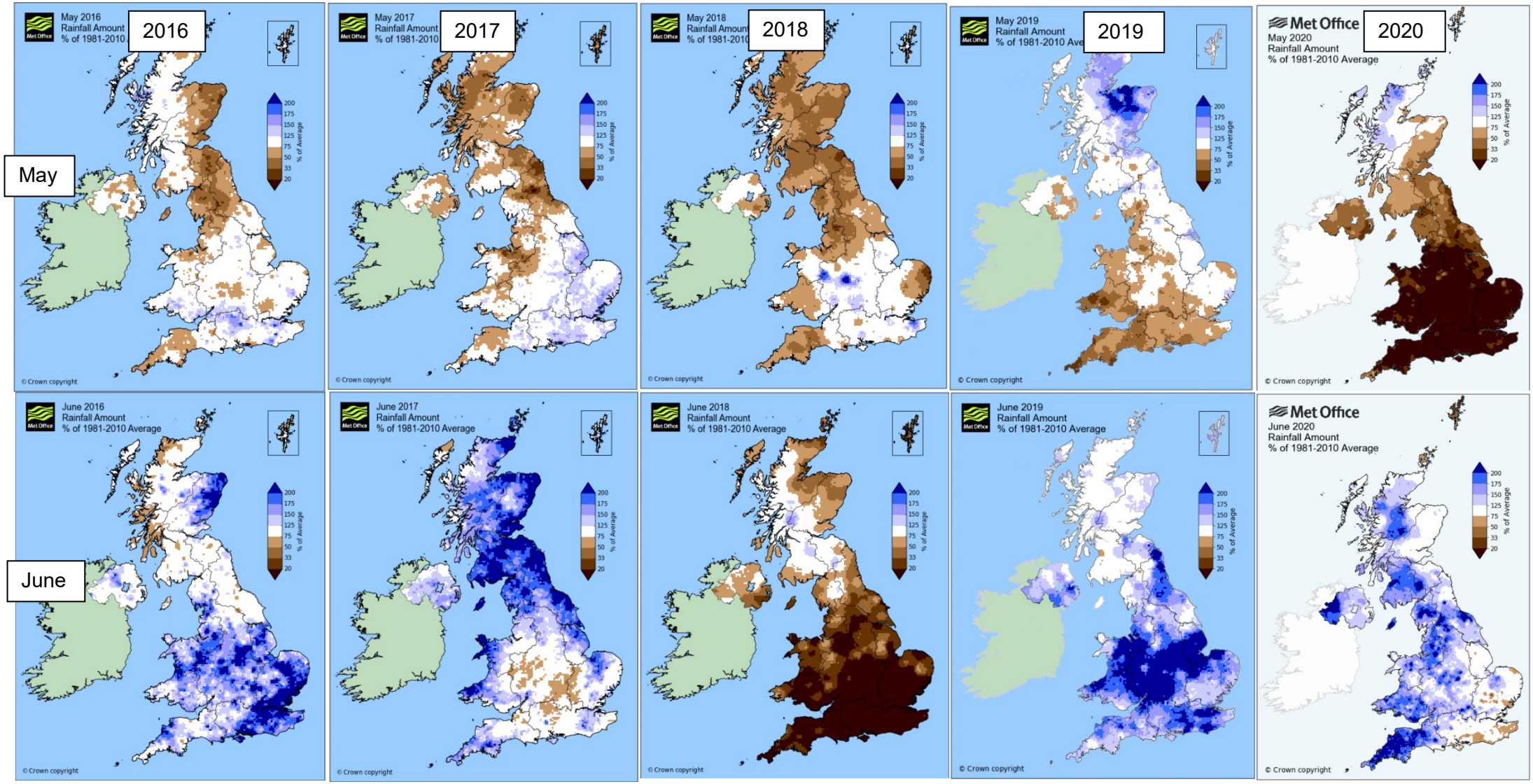

Figure 3: MET Office monthly anomaly maps showing rainfall in May and June for 2016 to 2020 as a percentage of the 1981 to 2010 average. Brown shows below average rainfall, white average and blue above average (MET Office, UK Actual and Anomaly Maps 2021b).

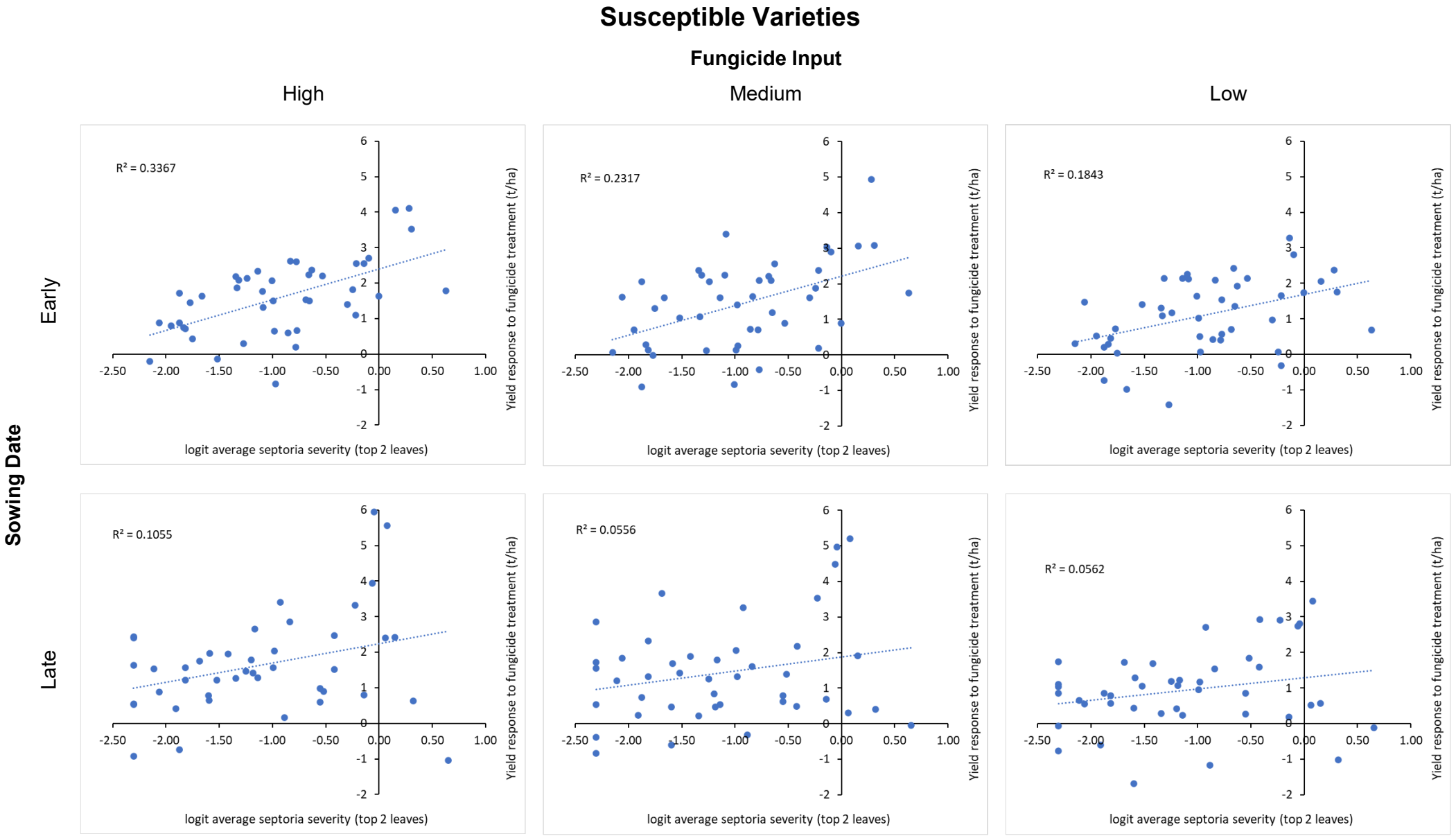

Figure 4: The correlation between septoria logit severity on untreated plots and fungicide yield response for each sowing date, fungicide combination in susceptible varieties.

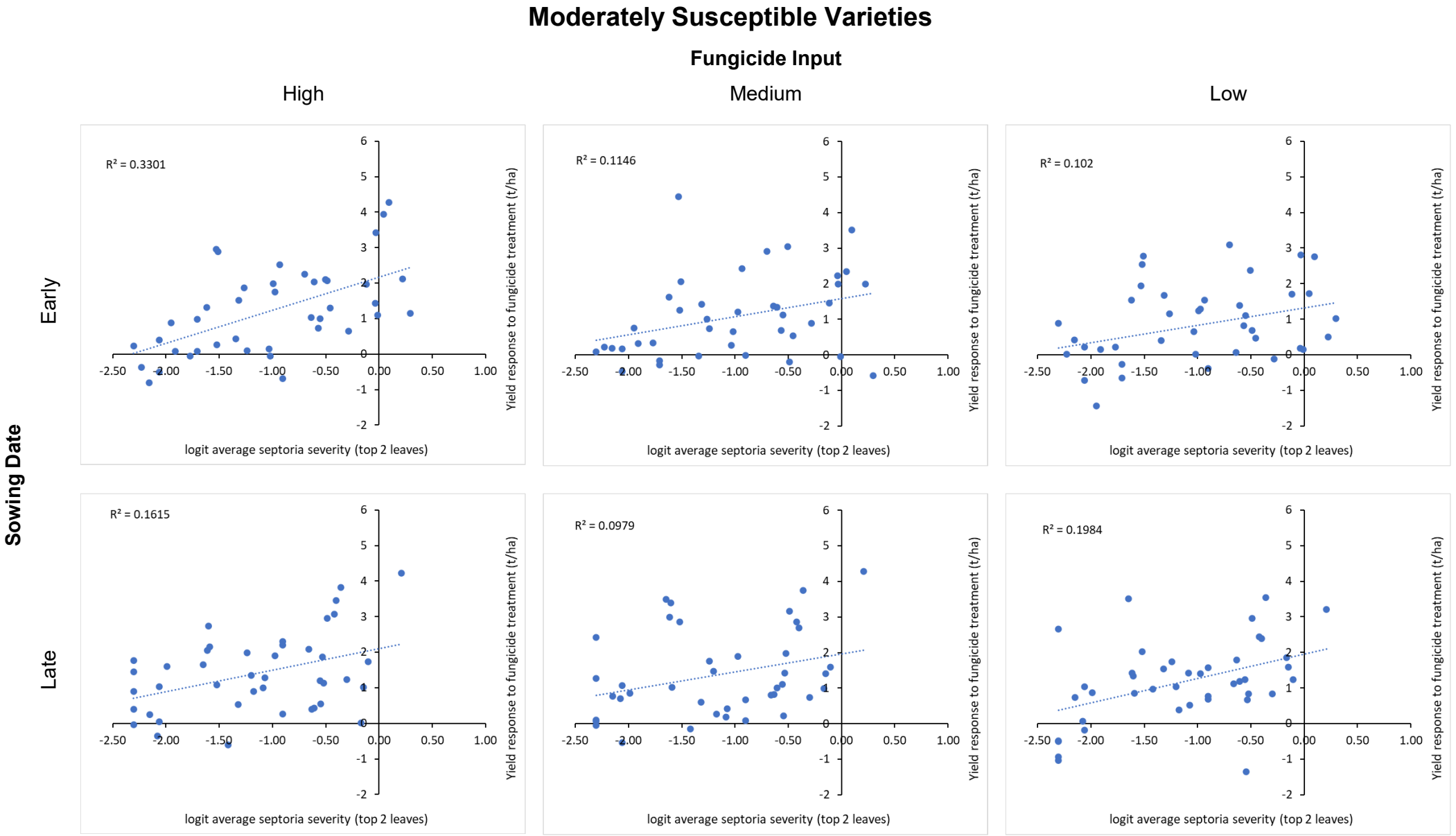

Figure 5: The correlation between septoria logit severity on untreated plots and fungicide yield response for each sowing date, fungicide combination in moderately susceptible varieties.

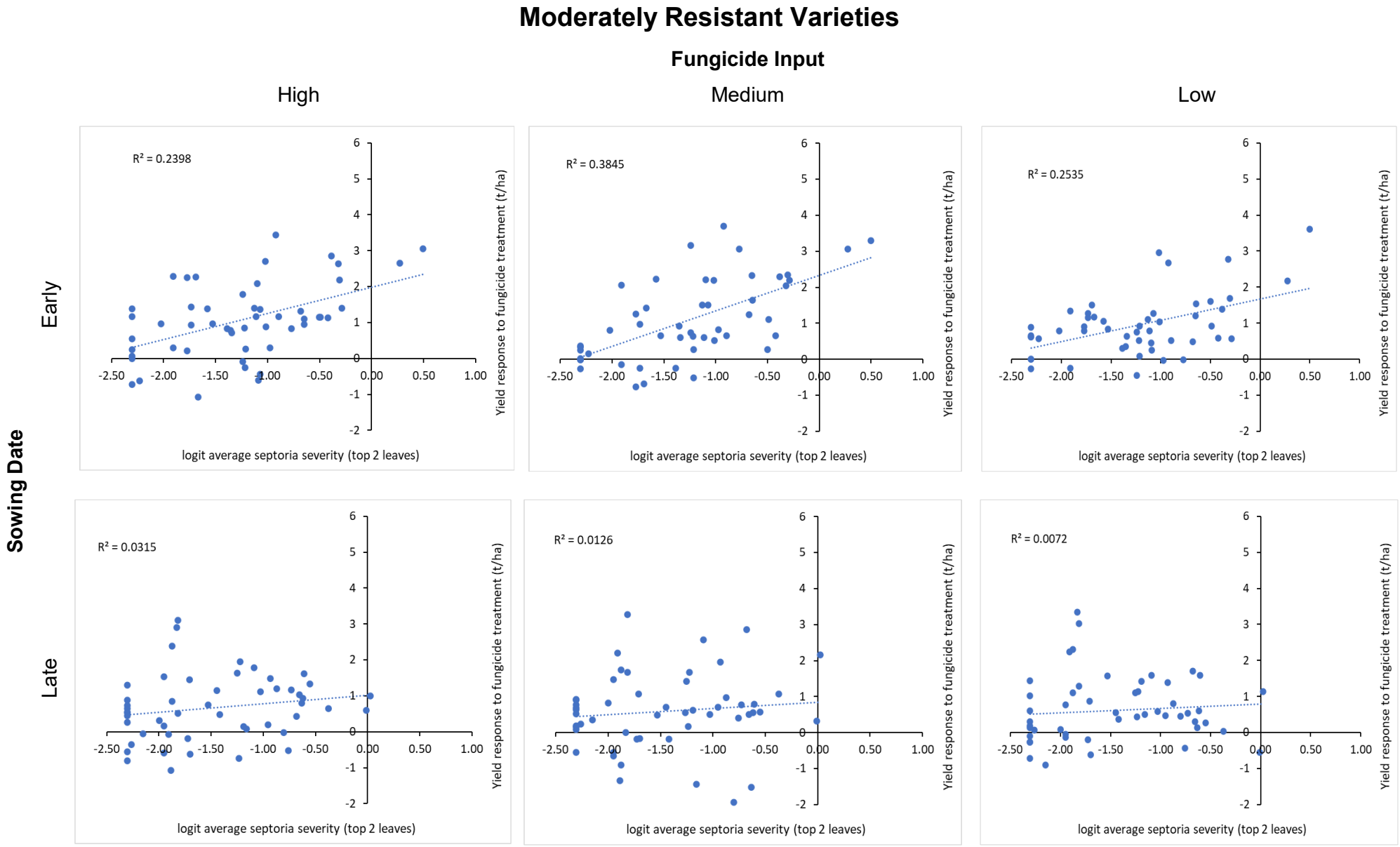

Figure 6: The correlation between septoria logit severity on untreated plots and fungicide yield response for each sowing date, fungicide combination in moderately resistant varieties.

4.2. Analysis by Season

Analysis of individual sites showed that seed rate was the least important factor affecting septoria in this project. Seed rate effects were inconsistent across sites and seasons. Therefore, this section will focus on the impact of sowing date, variety, and fungicide. The effects of seed rate are discussed in section 4.5.

4.2.1. 2016 season

In 2016, rainfall was above average in March for the south of the UK, average for most of the UK in April and May, and above average for the south of the UK in June (Figure 2, Figure 3).

T2 + 2-3 weeks disease assessment

Of the 6 sites in 2016, site 3 had the highest disease pressure on leaf 3 at T2 + 2-3 weeks, with an average septoria severity of 5.43% across all treatments. Site 4 had the lowest disease severity with an average of 0.89%.

Table 5: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks in 2016.

Factor	P Value
Site	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	0.005
Site.Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001
Site.Sowing.Variety.Fungicide	<.001

In addition to site differences, variety and fungicide were also found to be significant factors affecting septoria (Table 5). There were significant differences in disease pressure between each variety group, reflecting disease resistance ratings with the highest disease severity being observed in the most susceptible variety and the lowest in the most resistant (Table 6).

A significant interaction between variety and fungicide indicates that the response to fungicide differed by variety (Table 5). This was partly due to varietal differences in disease severity in the untreated. On average, there was no significant disease control benefit from applying more than a medium input fungicide programme in the susceptible and moderately susceptible varieties. In the moderately resistant varieties, there was no further benefit from applying more than a low input programme (Table 6). However, it should be noted that the significant interaction between site,

variety and fungicide suggests that the relationship between variety and fungicide was not consistent across sites, most likely due to the differences in the level of disease at each site (Appendix 1).

Table 6: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the variety and fungicide interaction in 2016, across sites 1 to 6.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	8.45	3.73	1.74	1.13	3.76
Moderately Susceptible	5.96	2.56	1.26	1.43	2.80
Moderately Resistant	2.63	0.90	0.88	0.46	1.22
Average	5.68	2.4	1.3	1.01	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.469	0.541	0.937		

The interaction between sowing date, variety and fungicide was not found to be statistically significant, suggesting that the relationship between variety and fungicide was consistent across sowing dates. However, it is clear that delaying sowing from mid-September to mid-October reduced the level of disease in the untreated of each variety so that a susceptible variety sown in mid-October was comparable to a moderately susceptible variety sown mid-September (Figure 7).

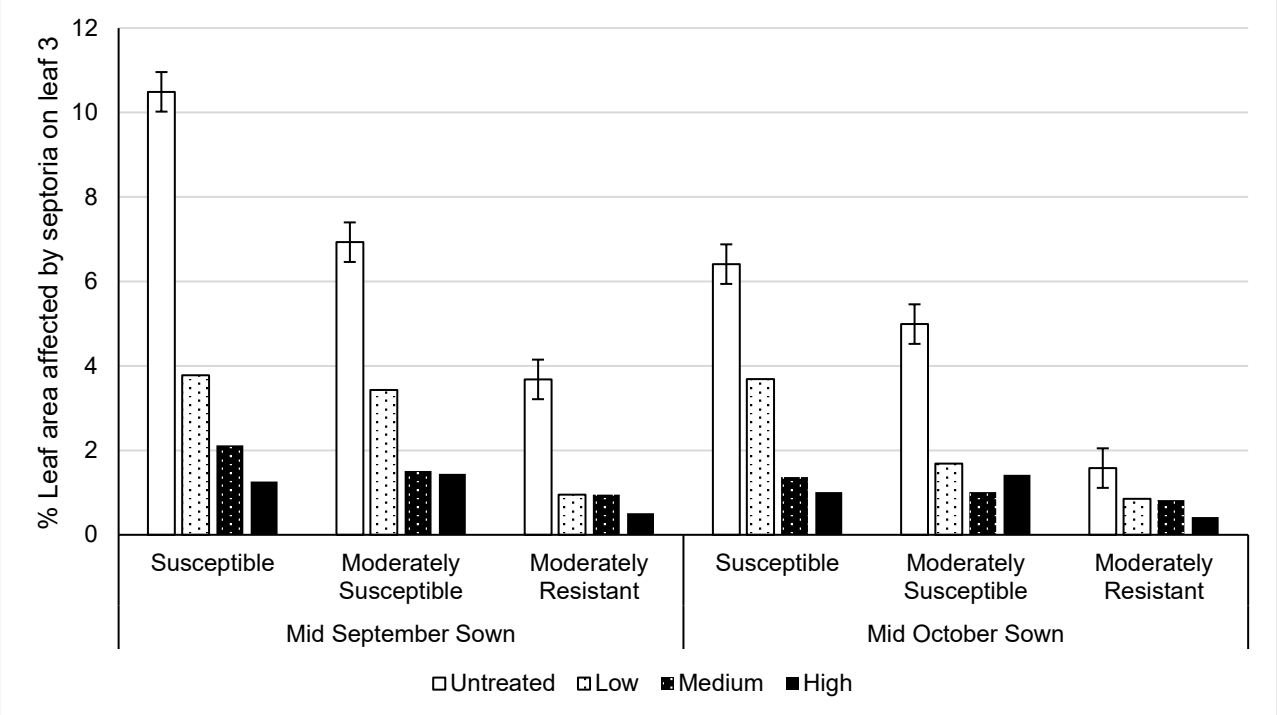

Figure 7: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks, for the interaction of sowing date, variety and fungicide in 2016 across sites 1 to 6. Error bars show the LSD for the interaction between variety and fungicide.

T2 + 6-8 weeks disease assessment

At T2 + 6 to 8 weeks, differences between sites were present with septoria severity at this time ranging from 2.77% at site 2 to 22.71% at site 6.

Table 7: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 2 at T2 + 6-8 weeks in 2016.

Factor	P Value
Site	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	0.041
Sowing.Seed Rate.Variety	<.001
Site.Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001
Site.Sowing.Seed Rate.Variety	0.014

Variety and fungicide were also found to be significant factors affecting septoria at this time (Table 7). The different varieties showed significant differences between each variety group, reflecting disease resistance ratings as at the earlier assessment (Table 8).

The interaction between variety and fungicide was also found to be statistically significant (Table 7). These results indicate that, on average, there was a significant benefit in disease control from applying the high input programme in the susceptible varieties, but that there was no significant benefit in applying more than a medium input programme for the moderately susceptible varieties and low input programme in the moderately resistant varieties (Table 8). However, as at the earlier assessment a significant interaction between site, variety and fungicide suggests that the relationship between variety and fungicide was not consistent across sites (Appendix 2).

Table 8: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the variety and fungicide interaction in 2016, across sites 1 to 6.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	31.73	15.04	7.57	4.26	14.65
Moderately Susceptible	24.38	12.46	6.25	4.78	11.97
Moderately Resistant	12.56	4.52	2.90	3.07	5.76
Average	22.89	10.67	5.57	4.03	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	1.445	1.669	2.89		

The interaction between sowing date, variety and fungicide was not found to be statistically significant, suggesting in 2016 that the relationship between variety and fungicide was consistent across sowing dates (Figure 8).

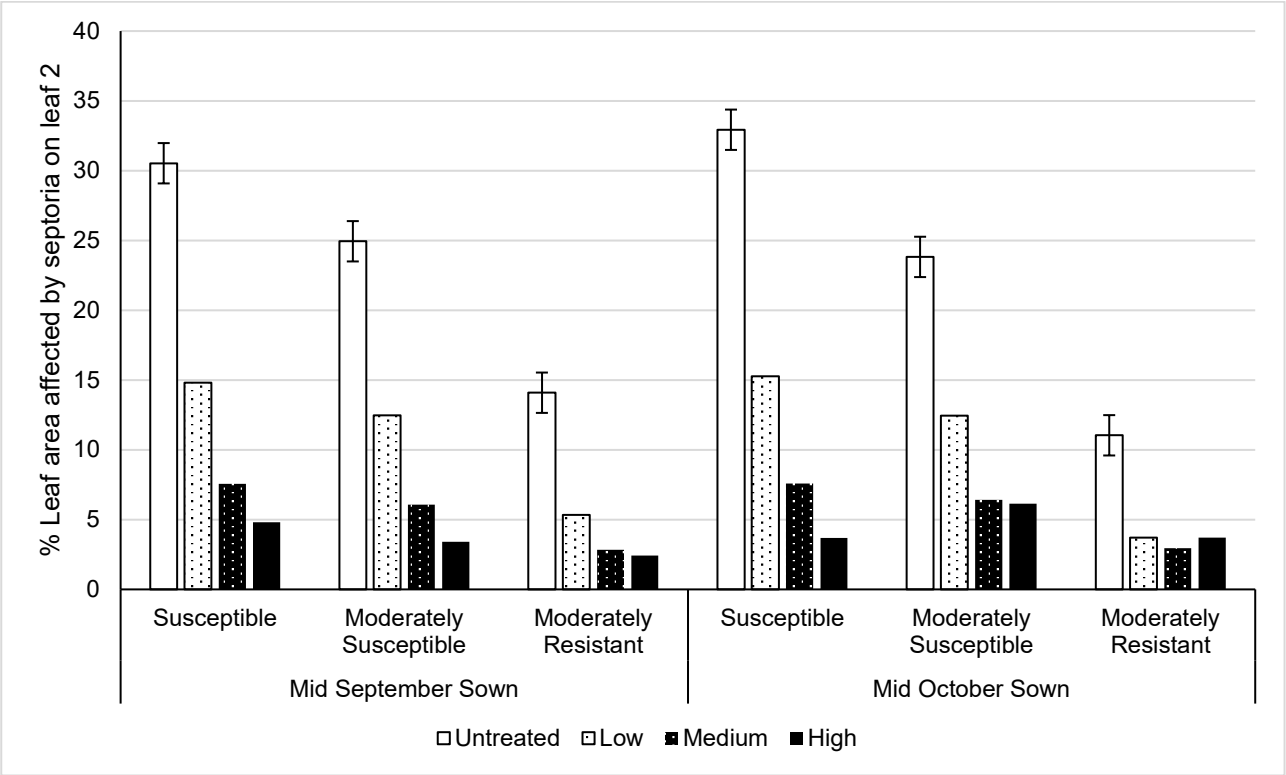

Figure 8: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks, for the interaction of sowing date, variety and fungicide in 2016, across sites 1 to 6. Error bars show the LSD for the interaction between variety and fungicide.

Yield

The impact of strategies was evaluated on yield based on data from 4 sites. Sites varied significantly with site 1 achieving the highest yield with an average of 10.34t/ha. Site 2 was the lowest yielding with an average of only 5.06t/ha.

Table 9: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for yield in 2016.

Factor	P Value
Site	<.001
Sowing	<.001
Seed Rate	<.001
Variety	<.001
Fungicide	<.001
Site.Seed Rate	0.025
Sowing.Seed Rate	<.001
Site.Variety	<.001
Site.Fungicide	0.01
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Seed Rate.Variety	0.003
Sowing.Seed Rate.Fungicide	0.039
Site.Variety.Fungicide	<.001
Site.Sowing.Seed Rate.Fungicide	<.001

Sowing date, seed rate, variety and fungicide were also found to significantly affect yield when considered on their own (Table 9). This is not surprising as sowing date, seed rate and variety can all influence yield in the absence of disease. On average, the late sown treatments yielded significantly higher than the early sown with 9.32t/ha compared to 8.34t/ha (Figure 9). Furthermore, the higher seed rate treatments had a higher yield on average, with 9.00t/ha compared to 8.66t/ha where lower seed rates had been implemented. When comparing the different varieties, the susceptible and moderately susceptible group were statistically comparable, whereas the moderately resistant group significantly increased yield compared to either of the other two groups (Table 10).

The interaction between variety and fungicide was also found to be statistically significant (Table 9), suggesting that the response to fungicide differed by variety (Table 10). On average the high input programme was optimal in the susceptible varieties, but there was no significant benefit in applying more than a medium input programme for the moderately susceptible and moderately resistant (Table 10). However, the interaction between site, variety and fungicide was also statistically significant, suggesting that the relationship between variety and fungicide was not consistent across sites (Appendix 3).

Table 10: Average yield (t/ha) for the variety and fungicide interaction in 2016, across sites 1, 2, 3 and 6.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	7.74	8.53	9.18	9.64	8.77
Moderately Susceptible	7.89	8.59	9.11	9.29	8.72
Moderately Resistant	8.39	8.96	9.27	9.39	9.00
Average	8.01	8.69	9.19	9.44	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.121	0.14	0.242		

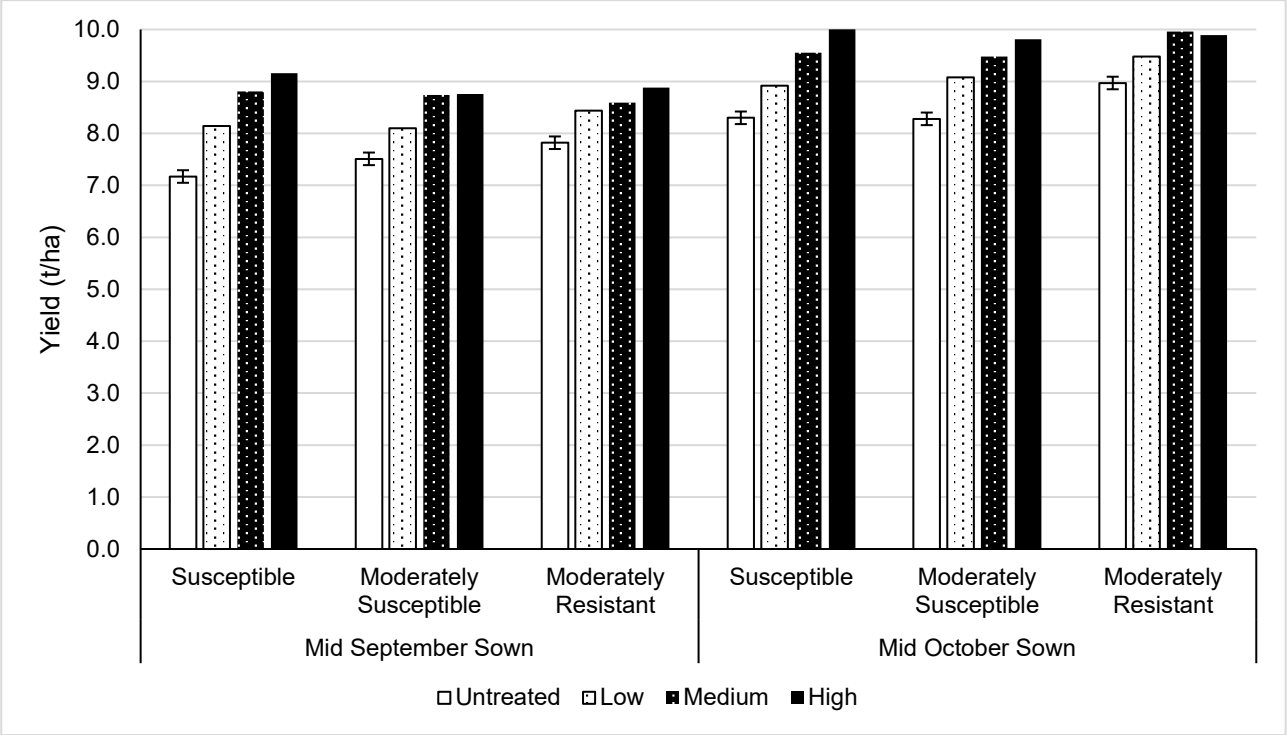

Figure 9: Average yield (t/ha), for the interaction of sowing date, variety and fungicide in 2016, across sites 1, 2, 3 and 6. Error bars show the LSD for the interaction between variety and fungicide.

Specific Weight

As specific weight is largely determined by variety, only the sites using the same three varieties have been analysed together. Differences between the 3 sites were small, ranging from an average of 70.27kg/hl at site 1 to 72.37kg/hl at site 3. Therefore, site was not found to be a significant factor affecting specific weight.

Table 11: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for specific weight in 2016.

Factor	P Value
Sowing	<.001
Site.Sowing	0.006
Seed Rate	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	0.022
Variety.Fungicide	<.001
Sowing.Seed Rate.Fungicide	<.001
Site.Sowing.Seed Rate.Fungicide	<.001

Sowing date, seed rate, variety and fungicide were all found to significantly affect specific weight as a single factor (Table 11). This is not surprising as sowing date, seed rate and variety can all influence specific weight in the absence of disease. On average, the late sowing had higher specific weight (Figure 10) than the early with 72.31kg/hl compared to 70.43kg/hl. The high seed rate had a slightly higher specific weight than the low seed rate with 71.58 kg/hl compared to 71.16kg/hl on average. When comparing the different varieties, all three were significantly different, Santiago (susceptible) had the lowest value and JB Diego (moderately susceptible) the highest (Table 12).

The interaction between variety and fungicide was also found to be statistically significant, suggesting that the response to fungicide differed by variety (Table 11). For Santiago, there was no significant benefit from applying more than a medium input programme. For JB Diego there was no significant benefit from applying more than a low input programme. Whereas, for Revelation (moderately resistant) there was no significant difference between the untreated and low input programme, but the medium input programme significantly increased specific weight compared to the untreated (Table 12). The interaction between site, variety and fungicide was not found to be significant, therefore indicating that this relationship was consistent across sites.

Table 12: Average specific weight (kg/hl) for the variety and fungicide interaction in 2016 across sites 1 to 3.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Santiago	67.30	69.75	70.68	71.09	69.71
JB Diego	72.12	73.18	73.60	73.32	73.05
Revelation	70.81	71.33	71.70	71.52	71.34
Average	70.08	71.42	71.99	71.98	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.300	0.347	0.601		

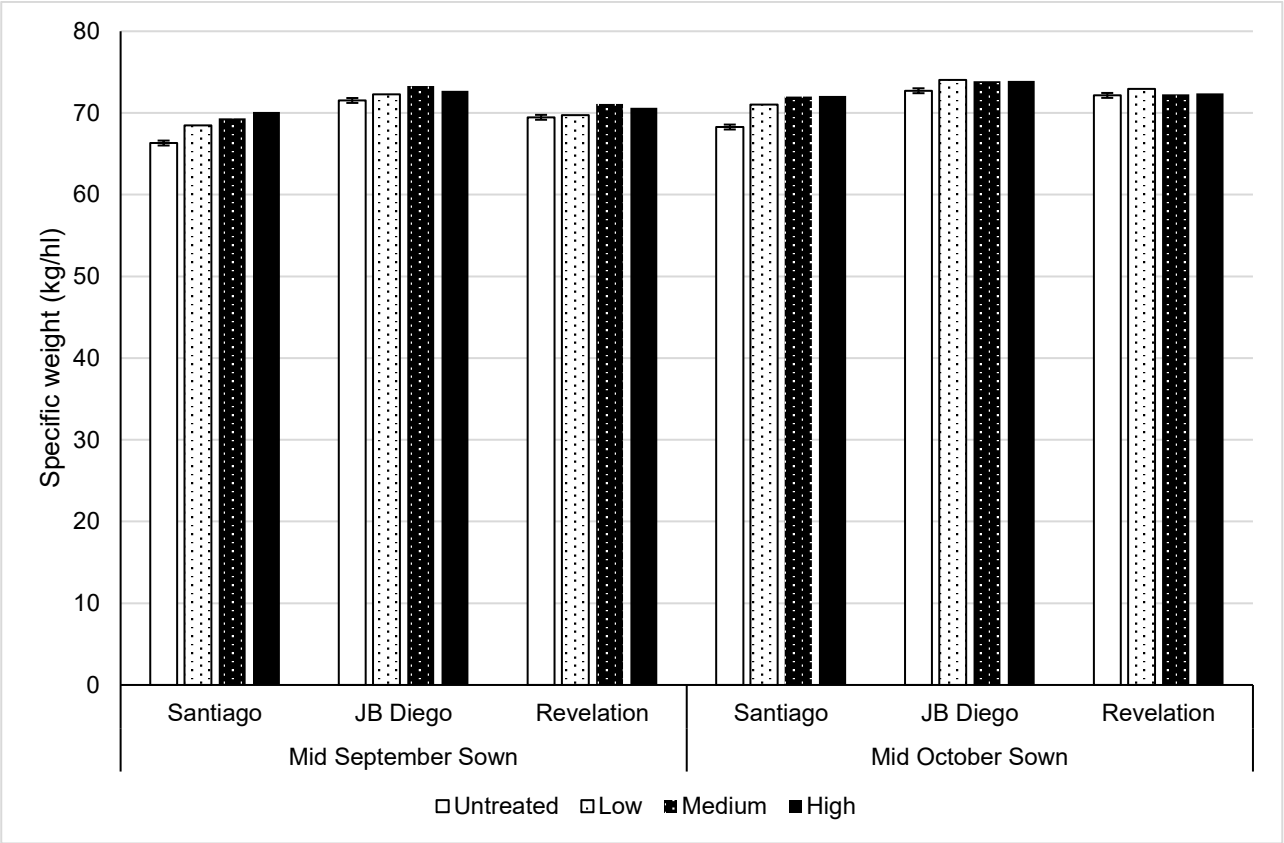

Figure 10: Average specific weight, for the interaction of sowing date, variety and fungicide in 2016 across sites 1 to 3. Error bars show the LSD for the interaction between variety and fungicide.

4.2.2. 2017 season

In 2017, rainfall was about average for most of the UK in March and well below average in April. In May, the North received below average rainfall whereas in the South it was closer to average. In June, rainfall was above average in the North and about average in the South (Figure 2, Figure 3).

T2 + 2-3 weeks disease assessment

At this early assessment timing, average septoria severity varied significantly, ranging from 2.27% at site 9 to 8.44% at site 7.

Table 13: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks in 2017.

Factor	**P Value**
Site	<.001
Sowing	<.001
Site.Sowing	0.028
Variety	<.001
Fungicide	<.001
Site.Seed Rate	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Seed Rate	0.003
Site.Seed Rate.Variety	<.001
Site.Sowing.Fungicide	0.031
Site.Seed Rate.Fungicide	<.001
Site.Variety.Fungicide	<.001
Site.Sowing.Seed Rate.Fungicide	<.001
Site.Seed Rate.Variety.Fungicide	<.001
Sowing.Seed Rate.Variety.Fungicide	<.001
Site.Sowing.Seed Rate.Variety.Fungicide	<.001

In addition to site differences, sowing date, variety and fungicide were also found to be significant factors affecting septoria at this time (Table 13). Early sowings had greater septoria severity on leaf 3 (Figure 11) than the late sowings with an average of 6.27% and 3.54% respectively. When comparing the different varieties, all three groups were significantly different with the highest disease severity in the susceptible group and lowest in the moderately resistant (Table 14).

The interaction between variety and fungicide was also found to be statistically significant (Table 13). On average there was a significant benefit in disease control from applying up to a medium input programme in the susceptible and moderately susceptible varieties, whereas for the moderately resistant varieties there was no further benefit from applying more than a low input programme (Table 14). However, as in 2016 the interaction between site, variety and fungicide was also statistically significant suggesting that the relationship between variety and fungicide was not consistent across sites (Appendix 4).

Table 14: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the variety and fungicide interaction in 2017, across sites, 7, 8, 9, 10 and 12.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	17.44	3.97	2.14	1.54	6.27
Moderately Susceptible	15.58	3.55	1.60	1.10	5.46
Moderately Resistant	8.40	1.58	1.13	0.84	2.99
Average	13.81	3.03	1.62	1.16	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.733	0.847	1.466		

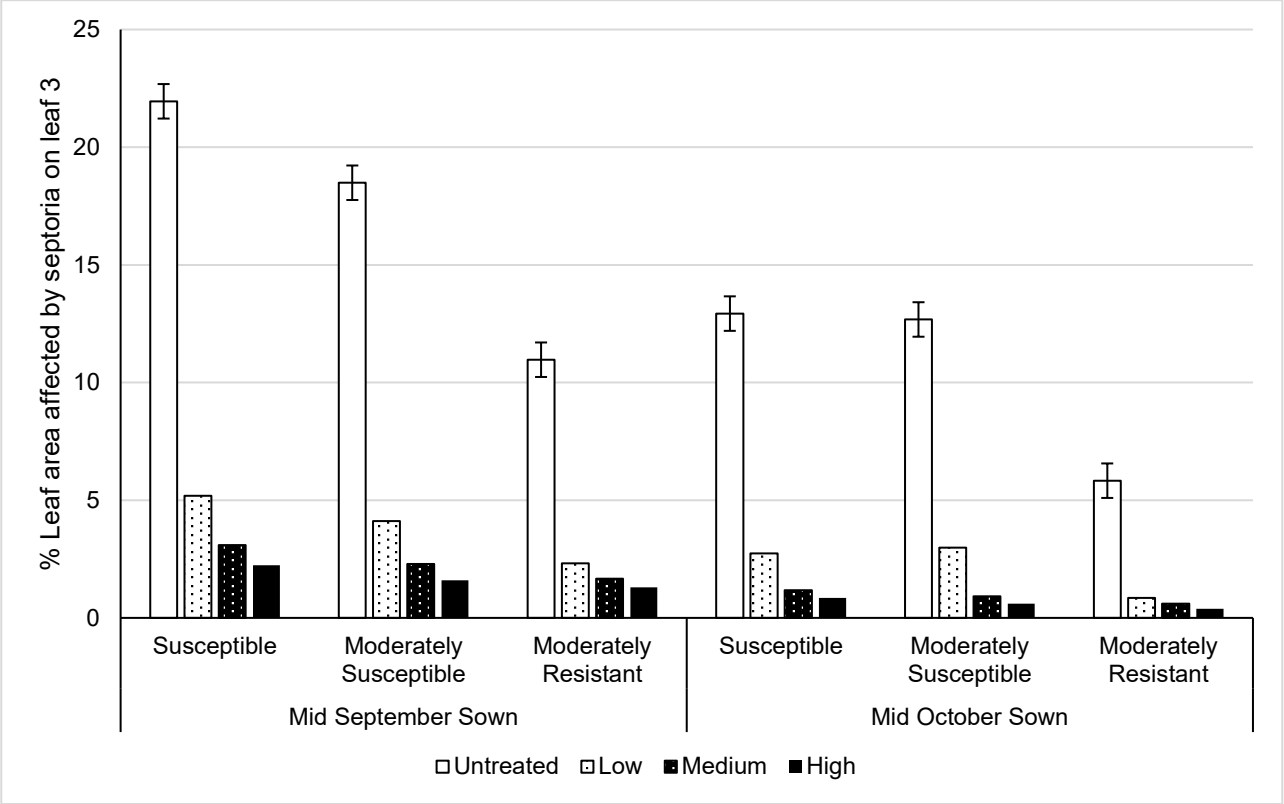

Figure 11: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks, for the interaction of sowing date, variety and fungicide in 2016, across sites, 7, 8, 9, 10 and 12. Error bars show the LSD for the interaction between variety and fungicide.

T2 + 6-8 weeks disease assessment

As at the earlier assessment, significant site differences were evident at this time with average septoria severity on leaf 2 ranging from 3.47% at site 9 to 16.03% at site 11.

Table 15: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 2 at T2 + 6-8 weeks in 2017.

Factor	P Value
Site	<.001
Sowing	0.003
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Seed Rate.Variety	0.042
Site.Fungicide	<.001
Variety.Fungicide	<.001
Sowing.Seed Rate.Variety	<.001
Site.Sowing.Fungicide	<.001
Site.Seed Rate.Fungicide	0.039
Site.Variety.Fungicide	<.001
Sowing.Variety.Fungicide	0.038
Site.Sowing.Seed Rate.Fungicide	0.018
Site.Sowing.Variety.Fungicide	<.001
Site.Seed Rate.Variety.Fungicide	0.045
Sowing.Seed Rate.Variety.Fungicide	<.001

Sowing date, variety and fungicide were also found to be significant as a single factor (Table 15). Early sowings had greater septoria severity than later sowings with an average of 10.77% compared to 8.00%. When comparing the different varieties, the susceptible and moderately susceptible groups were statistically comparable, whereas the resistant variety had significantly less disease on average.

The interaction between variety and fungicide was also found to be significant, indicating that the effect of fungicide varied by variety (Table 15). However, at this assessment, the relationship between variety and fungicide was affected by sowing date. When comparing the untreated values, there was no significant difference between sowing dates for the moderately susceptible variety whereas, for the susceptible and moderately resistant groups there was a significant reduction in disease when sown mid-October compared to mid-September. However, the response to fungicide was consistent across both sowing dates, as there was no significant benefit in disease control from applying more than a medium input strategy in the susceptible and moderately susceptible varieties, whereas for the moderately resistant group there was no significant benefit from applying more than a low input programme (Figure 12). The interaction between site, sowing date, variety and fungicide was also statistically significant suggesting that the relationship between sowing date, variety and fungicide was not consistent across sites (Appendix 5).

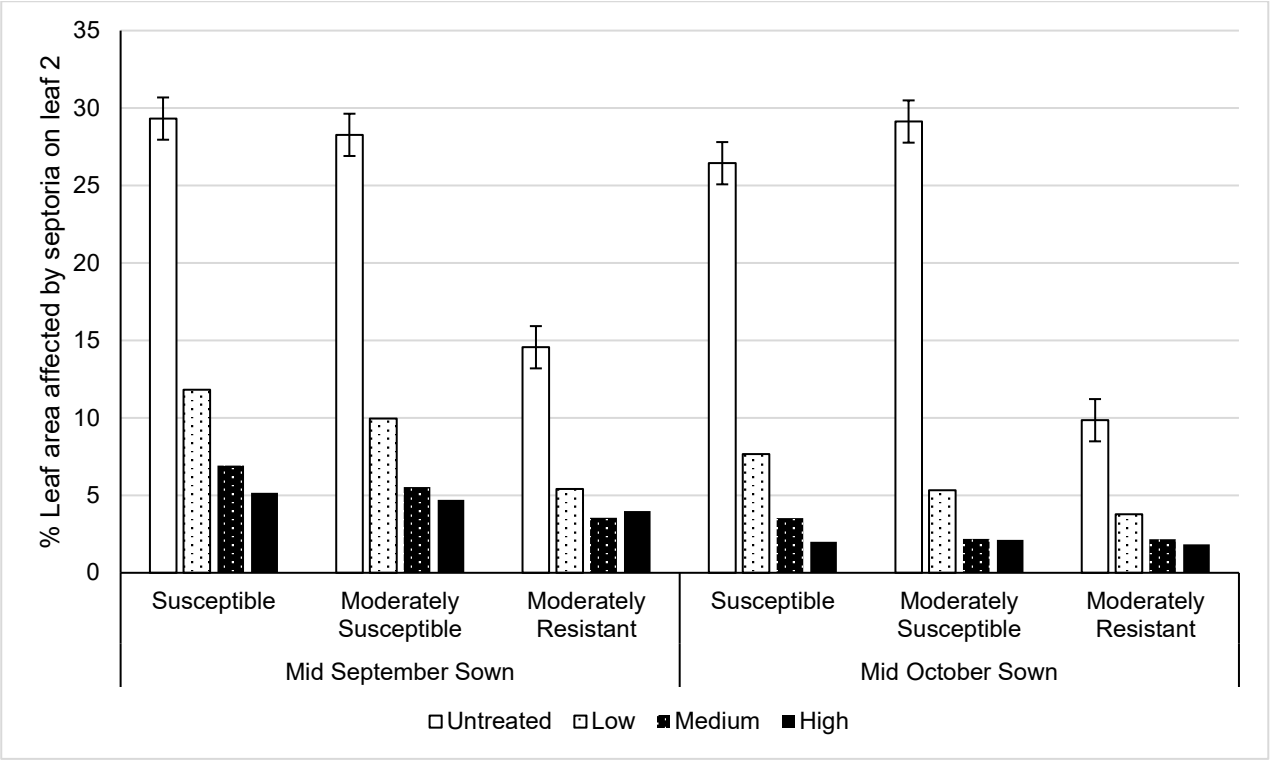

Figure 12: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks, for the interaction of sowing date, variety and fungicide in 2017, across sites 8, 9, 11 and 12. Error bars show the LSD for the interaction between sowing date, variety and fungicide.

Yield

The highest yielding site in 2017 was site 12, achieving 11.48t/ha, whilst the lowest yielding was site 8, with 8.31t/ha when averaged across all treatments.

Table 16: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for yield in 2017.

Factor	**P Value**
Site	<.001
Seed Rate	<.001
Variety	<.001
Fungicide	<.001
Site.Seed Rate	<.001
Sowing.Seed Rate	<.001
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Seed Rate	0.001
Site.Sowing.Variety	0.002
Site.Seed Rate.Variety	0.032
Site .Sowing.Fungicide	0.005
Site.Variety.Fungicide	<.001
Site.Sowing.Seed Rate.Fungicide	<.001
Site.Sowing.Variety.Fungicide	0.005

Seed rate, variety and fungicide were also found to be significant as a single factor (Table 16). On average, the higher seed rate achieved higher yields with 10.13t/ha, compared to 9.82t/ha for the lower seed rate. When comparing the three different varieties, the susceptible and moderately susceptible groups achieved significantly higher yields than the moderately resistant (Table 17).

The interaction between variety and fungicide was also found to be significant (Table 16). On average, there was no significant benefit in yield from applying more than a medium input programme in the susceptible variety, or a low input programme in the moderately susceptible and moderately resistant varieties (Table 17). However, a significant interaction between site, variety and fungicide indicates that the relationship between variety and fungicide was not consistent across sites (Appendix 6).

Table 17: Average yield (t/ha) for the variety and fungicide interaction in 2017, across sites 7 to 12.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	8.73	10.16	10.65	10.74	10.07
Moderately Susceptible	9.11	10.24	10.35	10.35	10.01
Moderately Resistant	9.18	9.99	10.10	10.12	9.85
Average	9.00	10.13	10.37	10.40	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.115	0.133	0.230		

The interaction between sowing date, variety and fungicide was not found to be statistically significant in 2017, as yield values were similar whether sown mid-September or mid-October (Figure 13).

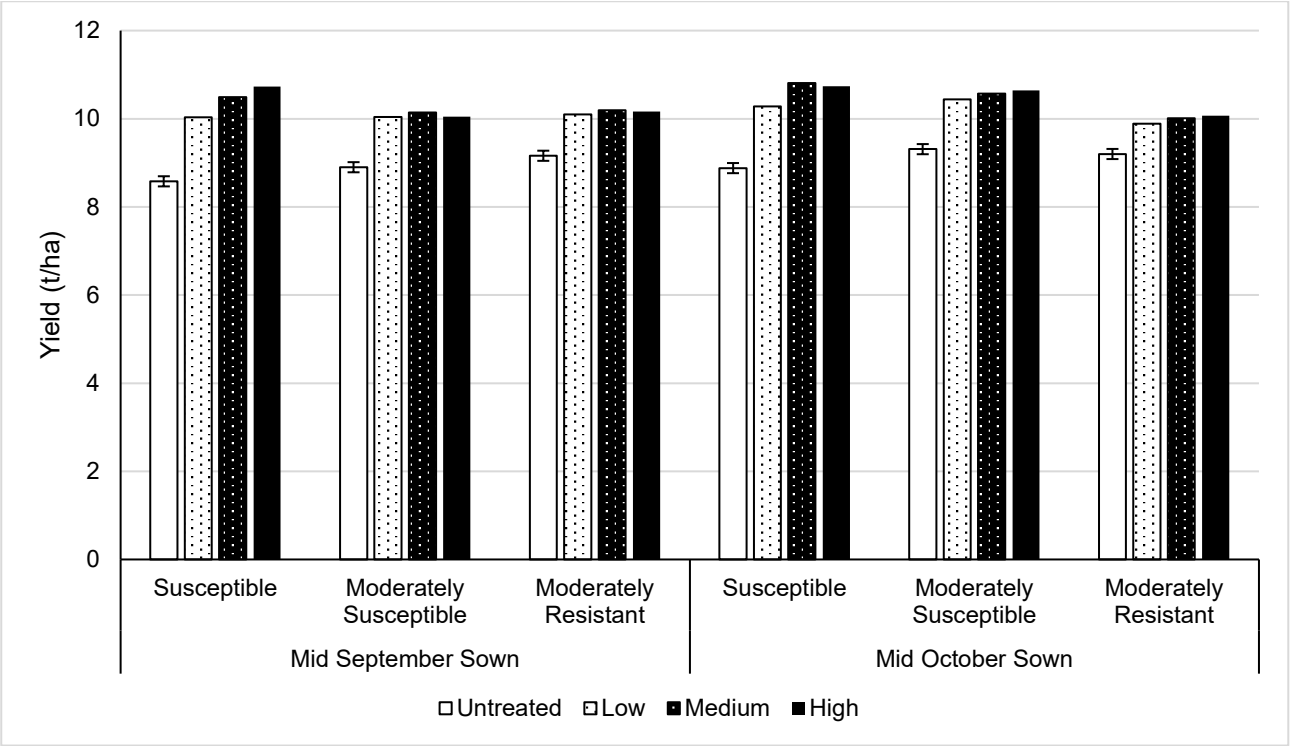

Figure 13: Average yield (t/ha), for the interaction of sowing date, variety and fungicide in 2017, across sites 7 to 12. Error bars show the LSD for the interaction between variety and fungicide.

Specific weight

In 2017 there was a significant difference in the specific weight values achieved by each site. Of the 4 sites included in this analysis, site 8 had the highest values with an average of 72.78kg/hl and site 10 the lowest with 67.53kg/hl.

Table 18: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for specific weight in 2017.

Factor	**P Value**
Site	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	0.03
Seed Rate.Fungicide	0.022
Variety.Fungicide	<.001
Site.Sowing.Seed Rate	0.025
Site.Sowing.Variety	0.027
Site .Sowing.Fungicide	0.008
Site.Variety.Fungicide	<.001
Site.Sowing.Variety.Fungicide	0.019

Variety and fungicide were also found to be significant as a single factor (Table 18). On average, JB Diego achieved the highest specific weight, significantly higher than Santiago or Revelation which were comparable (Table 19).

The interaction between variety and fungicide was also significant (Table 18). This is because for Santiago there was a significant benefit of fungicides up to the medium input programme, whereas for JB Diego and Revelation there was no further benefit from going above a low input programme (Table 19). However, the interaction between site, variety and fungicide was also statistically significant suggesting that this relationship was not consistent across sites (Appendix 7).

Table 19: Average specific weight (kg/hl) for the variety and fungicide interaction in 2017, across sites 7, 8, 9 and 10.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Santiago	68.36	69.99	70.46	70.28	69.77
JB Diego	72.08	72.92	72.64	72.65	72.57
Revelation	69.14	69.74	69.96	69.79	69.66
Average	69.86	70.88	71.02	70.91	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.198	0.229	0.396		

The interaction between sowing date, variety and fungicide was not significant suggesting that the relationship between variety and fungicide was consistent across sowing dates (Figure 14).

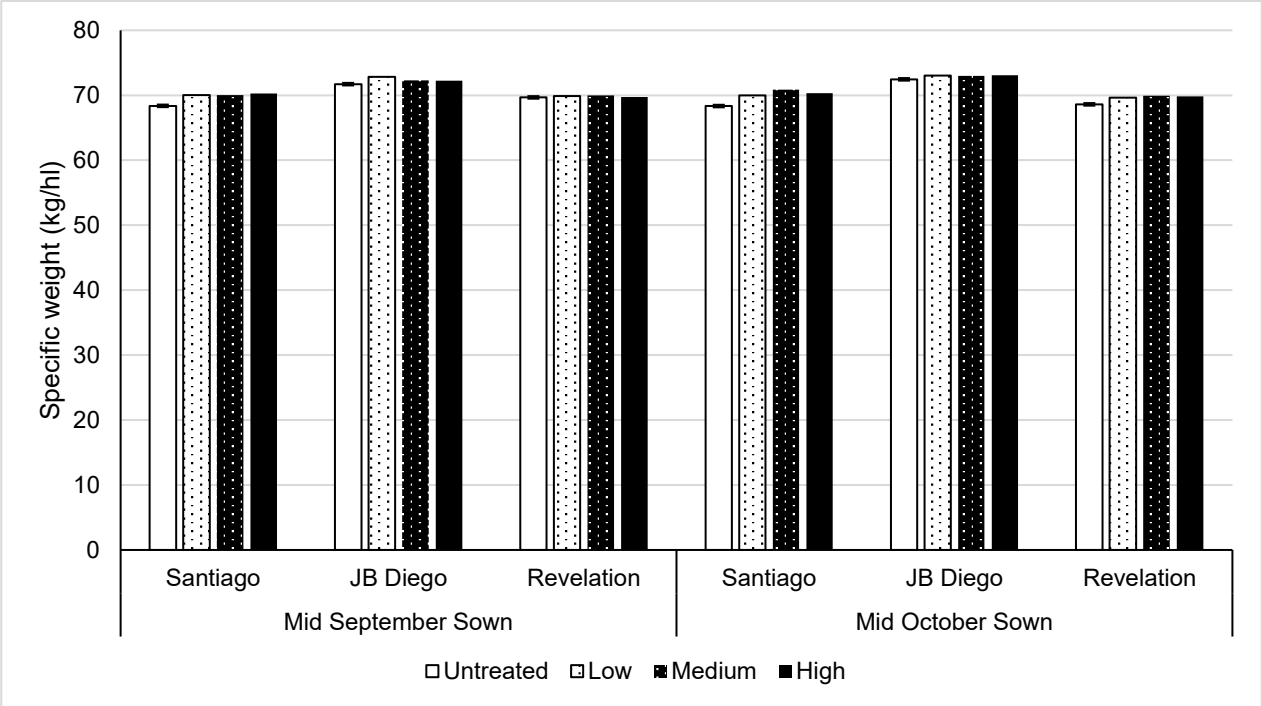

Figure 14: Average specific weight, for the interaction of sowing date, variety and fungicide in 2017, across sites 7, 8, 9 and 10. Error bars show the LSD for the interaction between variety and fungicide.

4.2.3. 2018 season

In 2018, rainfall was well above average for most of the UK in March and above average in April. In May, rainfall was close to average in the South of the UK but below average in the North, whereas in June rainfall was well below average across most of the UK (Figure 2, Figure 3).

T2 + 2-3 weeks disease assessment

Disease pressure was highest at site 13 at this time with a severity of 18.21% when averaged across all treatments, whereas site 14 had significantly less disease on leaf 3 with 1.77%.

Table 20: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks in 2018.

Factor	P Value
Site	<.001
Sowing	<.001
Site.Sowing	<.001
Seed Rate	0.001
Variety	<.001
Fungicide	<.001
Sowing.Seed Rate	0.035
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site .Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001
Site.Sowing.Variety.Fungicide	<.001

Sowing date, seed rate, variety and fungicide were also found to be significant factors affecting septoria severity on leaf 3 (Table 20). On average early sowings had greater septoria severity than later sowings with 10.67% compared to 6.21%. Furthermore, the higher seed rates also had greater septoria severity than lower seed rates with 9.04% compared to 7.84%. When comparing the different varieties, there were significant differences in disease pressure between each group, reflecting disease resistance ratings, with the highest disease severity in the susceptible group and lowest in the moderately resistant (Table 21).

The interaction between variety and fungicide was also found to be statistically significant due to differences in the level of disease in the untreated of each variety (Table 20). However, the response to fungicide across all three variety groups was comparable as there was no significant benefit from applying more than a low input fungicide programme at this time (Table 21). The

interaction between site, variety and fungicide was also statistically significant suggesting that the relationship between variety and fungicide was not consistent across sites (Appendix 8).

Table 21: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the variety and fungicide interaction in 2018, across sites 13, 14, 15, 17 and 18.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	29.99	7.44	9.51	5.89	13.21
Moderately Susceptible	20.73	4.99	4.71	3.27	8.43
Moderately Resistant	8.95	2.25	2.22	1.34	3.69
Average	19.89	4.90	5.48	3.50	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.888	1.025	1.776		

The interaction between sowing date, variety and fungicide was not found to be significant, suggesting that the relationship between variety and fungicide was consistent across sowing dates. However, it is clear that sowing in mid-October reduced the level of disease in the untreated of each variety compared to sowing in mid-September. This meant that a susceptible variety sown in mid-October was comparable to a moderately susceptible variety sown mid-September (Figure 15).

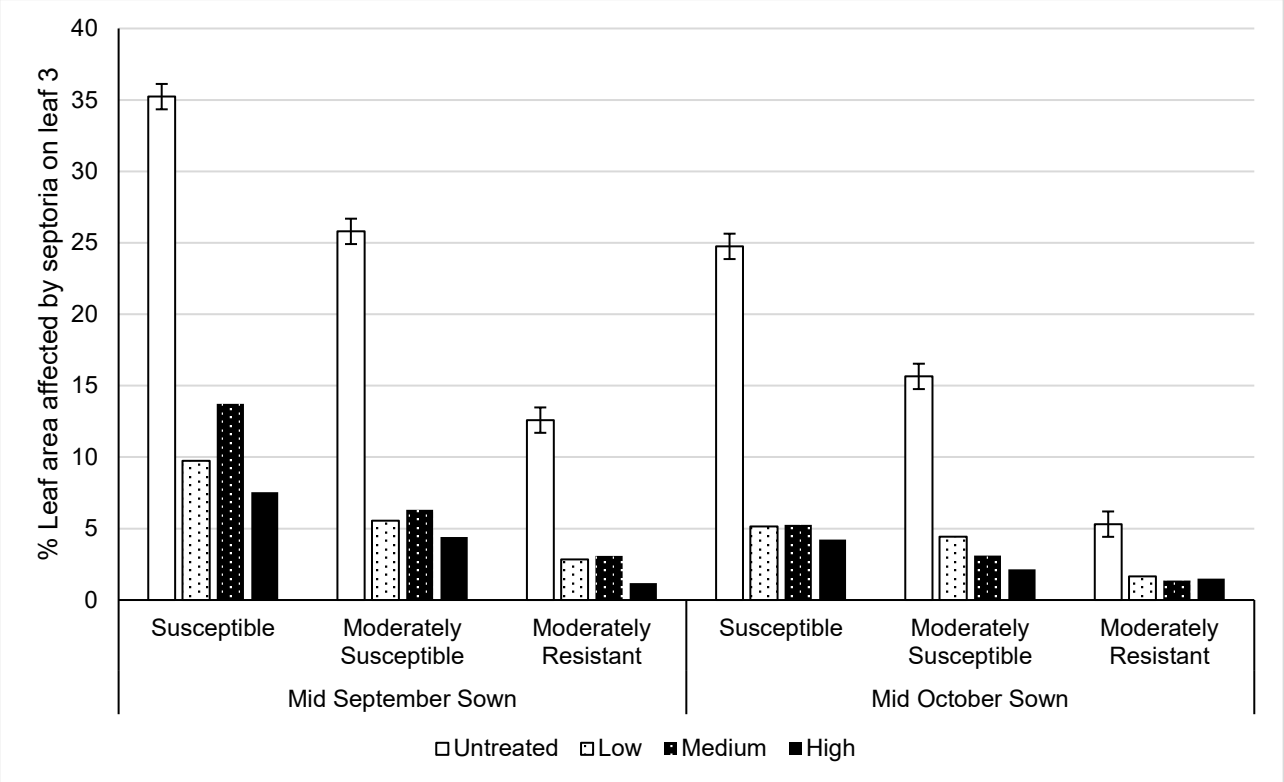

Figure 15: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks, for the interaction of sowing date, variety and fungicide in 2018, across sites 13, 14, 15, 17 and 18. Error bars show the LSD for the interaction between variety and fungicide.

T2 + 6-8 weeks disease assessment

Due to the dry conditions in May and June disease progress was slow in 2018 and therefore final disease levels were relatively low compared to the other seasons. However, the site differences seen earlier were still evident. The highest level of disease on leaf 2 was seen at site 15, with a septoria severity value of 5.79% when average across all treatments. The lowest was at site 16, with just 0.21%.

Table 22: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 2 at T2 + 6-8 weeks in 2018.

Factor	P Value
Site	<.001
Sowing	0.015
Site.Sowing	<.001
Seed Rate	0.002
Variety	<.001
Fungicide	<.001
Site.Seed Rate	0.016
Site.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	0.004
Seed Rate.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	0.002
Site.Seed Rate.Fungicide	<.001
Site.Variety.Fungicide	<.001
Sowing.Variety.Fungicide	0.041
Site.Sowing.Variety.Fungicide	0.003

Sowing date, seed rate, variety and fungicide were also found to be significant factors that affected septoria severity (Table 22). At this time, on average, late sowing had slightly higher septoria severity than early sowing with 3.80% and 3.27% respectively. This result differs from both the earlier assessment in this year and from the effect of sowing date in previous seasons. This may be due to an underestimation of disease in the early sowing due to early senescence following dry conditions in May and June. The higher seed rate had greater septoria severity on average than the low seed rate with 3.92% compared to 3.15%. When comparing the different varieties, all three groups were significantly different and reflected their resistance ratings.

The interaction between variety and fungicide was found to be significant, suggesting that the fungicide effect varied by variety. However, this relationship was affected by sowing date (Table 22). When comparing the levels of disease where no fungicides were applied (untreated), the susceptible variety sown in mid-October had significantly less septoria than when sown mid-September. Whereas the moderately susceptible and moderately resistant varieties showed no

significant difference by sowing date. Furthermore, for most varieties there was no significant benefit from applying more than a low input fungicide programme whether sown mid-September or mid-October. However, there was one exception, where the moderately susceptible group was sown mid-October there was a significant benefit from applying up to a medium input strategy (Figure 16). The interaction between site, sowing date, variety and fungicide was also statistically significant suggesting that the relationship between sowing date, variety and fungicide was not consistent across sites (Appendix 9).

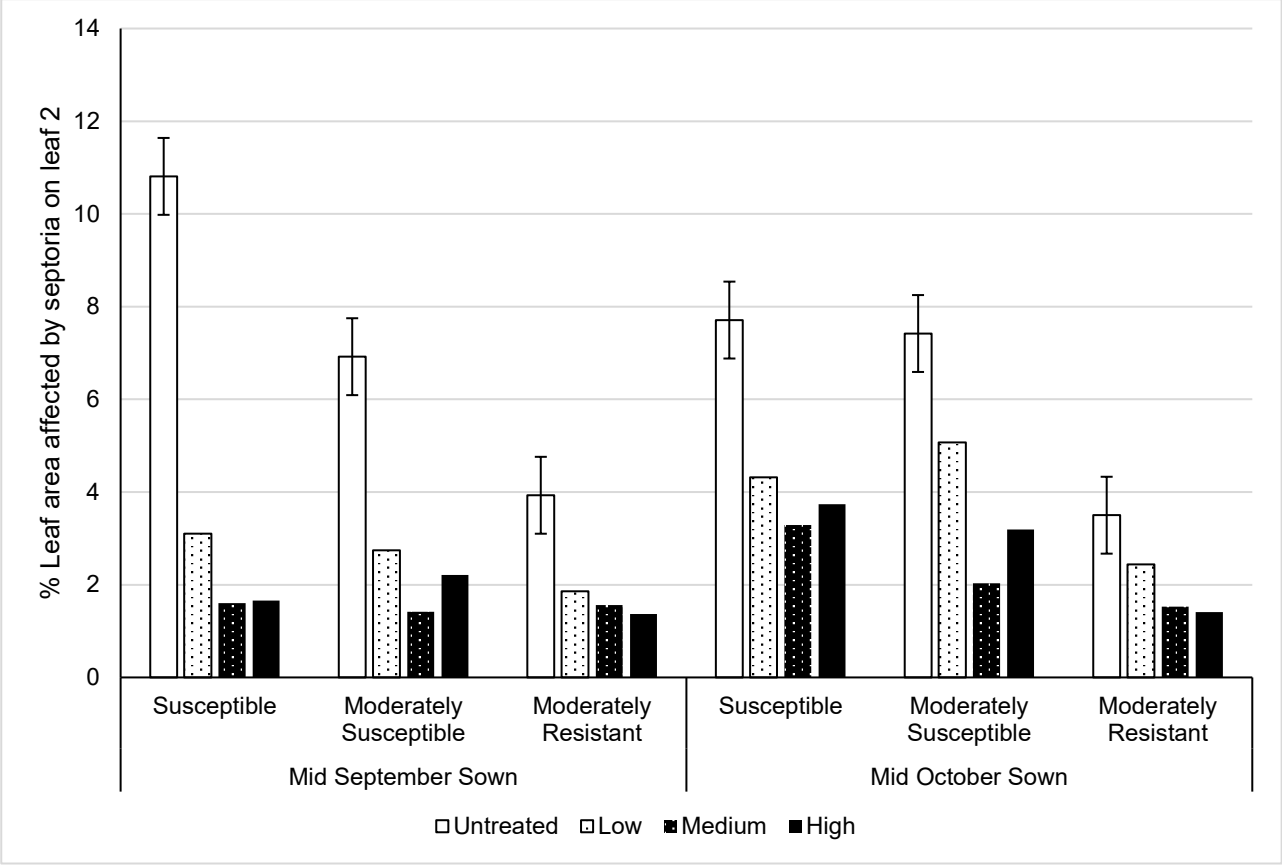

Figure 16: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks, for the interaction of sowing date, variety and fungicide in 2018, across sites 14, 15, 16 and 18. Error bars show the LSD for the interaction between sowing date, variety and fungicide.

Yield

Of the 5 sites analysed here, the highest yielding site was 18 with an average of 11.92t/ha, the lowest yielding site was 16 with 8.93t/ha. Therefore, site was found to be a significant factor affecting yields.

Table 23: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for yield in 2018.

Factor	P Value
Site	<.001
Seed Rate	<.001
Variety	<.001
Fungicide	<.001
Site.Seed Rate	<.001
Site.Variety	<.001
Sowing.Variety	0.001
Site.Fungicide	<.001
Variety.Fungicide	0.016
Site.Sowing.Seed Rate	0.002
Site.Sowing.Variety	0.008
Site.Seed Rate.Fungicide	<.001
Site.Variety.Fungicide	<.001
Site.Seed Rate.Variety.Fungicide	0.003

Seed rate, variety and fungicide were also found to significantly affect yield as a single factor (Table 23). On average, the higher seed rates achieved a higher yield with 10.65t/ha compared to 10.25t/ha where lower seed rates were implemented. When comparing the different varieties, all three groups were significantly different, the susceptible group achieving the highest yield and moderately susceptible the lowest (Table 24).

The interaction between variety and fungicide was also found to be statistically significant, suggesting that the response to fungicide differed by variety (Table 23). On average, there was a significant increase in yield from applying up to a medium input programme in the susceptible and moderately susceptible varieties, whereas for the moderately resistant, there was no further benefit from applying more than a low input fungicide programme (Table 24). However, the interaction between site, variety and fungicide was also statistically significant suggesting that the relationship between variety and fungicide was not consistent across sites (Appendix 10).

Table 24: Average yield (t/ha) for the variety and fungicide interaction in 2018, across sites 13, 14, 15, 16 and 18.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	10.02	10.58	10.99	10.98	10.64
Moderately Susceptible	9.67	10.29	10.61	10.52	10.27
Moderately Resistant	10.01	10.51	10.48	10.71	10.43
Average	9.90	10.46	10.69	10.74	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	0.016		
LSD	0.11	0.127	0.22		

The interaction between sowing date, variety and fungicide was not found to be statistically significant in 2018, suggesting that the interaction between variety and fungicide was similar across sowing dates (Figure 17).

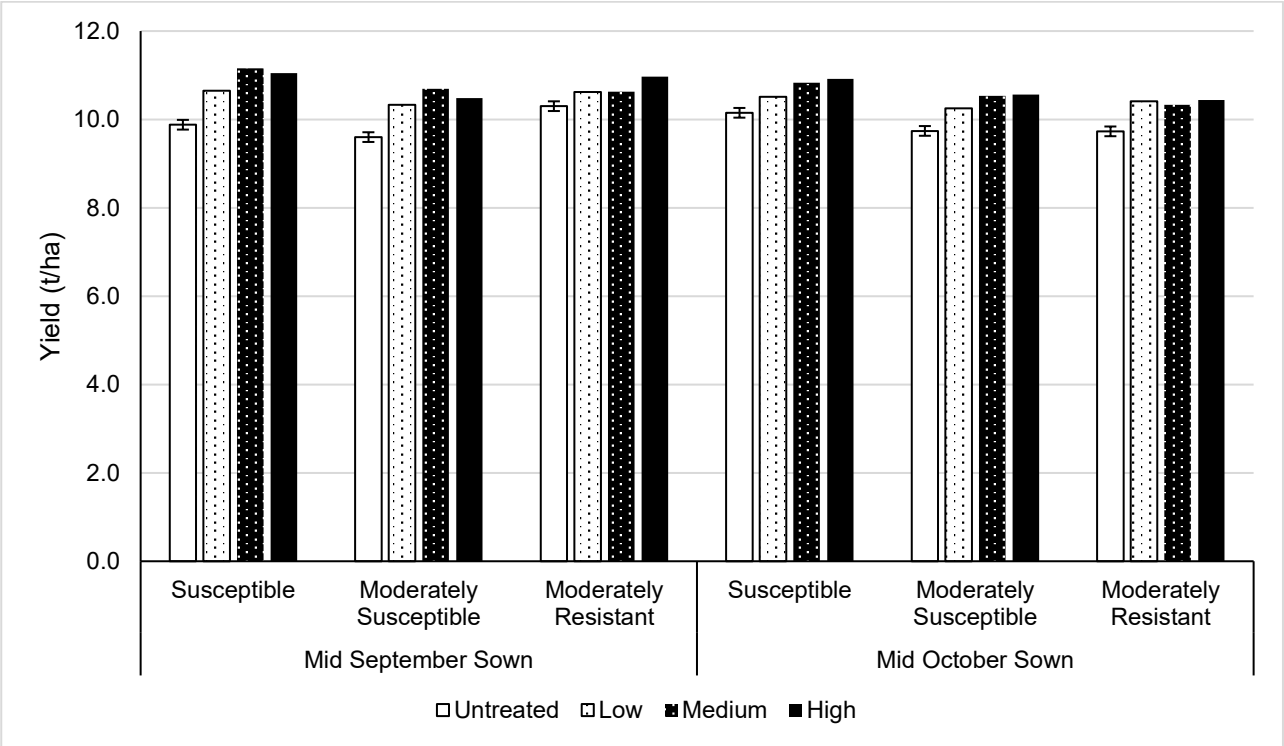

Figure 17: Average yield (t/ha), for the interaction of sowing date, variety and fungicide in 2018, across sites 13, 14, 15, 16 and 18. Error bars show the LSD for the interaction between variety and fungicide.

Specific weight

Significant differences in specific weight between sites were evident in 2018, with site 14 achieving the highest specific weight with an average of 77.53kg/hl, and site 16 having the lowest values with an average of 73.44kg/hl.

Table 25: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for specific weight in 2018.

Factor	P Value
Site	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Seed Rate.Variety	0.007
Site.Variety.Fungicide	<.001
Sowing.Variety.Fungicide	0.02

Variety and fungicide were also found to significantly affect specific weight as a single factor (Table 25). When comparing the different varieties, all three varieties were significantly different. JB Diego achieved the highest values and Santiago the lowest.

The interaction between variety and fungicide was found to be statistically significant (Table 25). However, the interaction between sowing date, variety and fungicide was also significant, suggesting that the relationship between variety and fungicide was affected by sowing date. This is because when sown mid-September, specific weight significantly increased in Santiago between the untreated and low input fungicide programme and low input and medium input programme, but there was no further benefit from the high input programme. In JB Diego, there was no significant difference between the untreated and low input programme, however the medium input programme did significantly increase specific weight compared to the untreated. Whereas in Revelation there was no significant differences between any of the fungicide inputs. When sown in mid-October, for Santiago, there was no significant difference between the untreated and low input programme, however, the medium input programme did significantly increase specific weight compared to the untreated. However, for both JB Diego and Revelation there was no significant differences between any of the fungicide inputs (Figure 18).

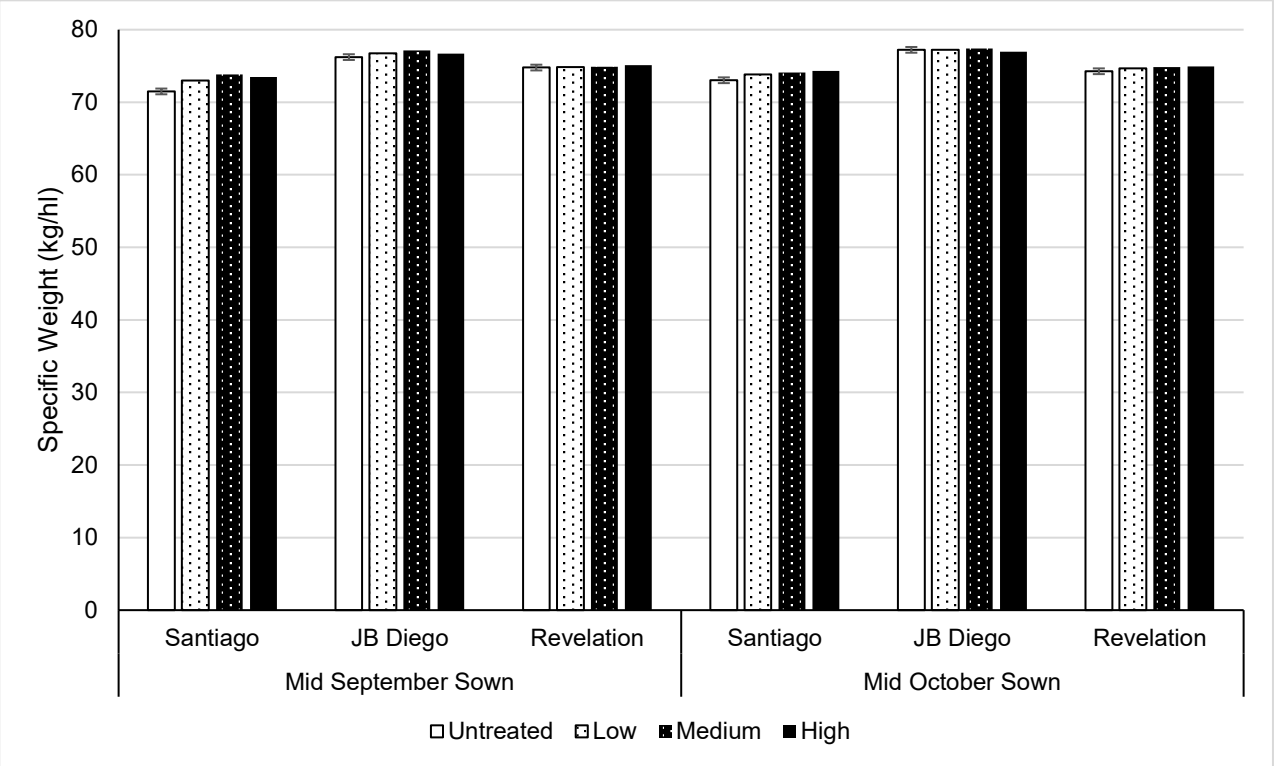

Figure 18: Average specific weight, for the interaction of sowing date, variety and fungicide in 2018, across sites 13, 14, 15 and 16. Error bars show the LSD for the interaction between sowing date, variety and fungicide.

4.2.4. 2019 season

In 2019, rainfall was above average in the North and about average in the south during March. In April, for most areas of the UK rainfall was below average, whereas in May the south west received below average rainfall, and the rest of the UK was close to average. In June rainfall was above average, particularly in the Midlands (Figure 2, Figure 3).

T2 + 2-3 weeks disease assessment

Significant differences in disease pressure were observed between sites at this time with septoria on leaf 3 ranging from 0.28% at site 21 to 8.16% at site 19.

Table 26: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks in 2019.

Factor	P Value
Site	<.001
Sowing	0.013
Site.Sowing	0.013
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001
Sowing.Variety.Fungicide	0.03
Site.Sowing.Variety.Fungicide	0.046

Sowing date, variety and fungicide were also found to be significant factors affecting septoria severity (Table 26). Early sowings had greater septoria severity than late sowings, with an average (across all factors) of 6.35% compared to 2.09%. Each variety group had a significantly different level of disease, reflecting their resistance ratings as the susceptible group had the highest severity and moderately resistant group the lowest.

The effect of fungicide differed by variety however, the interaction between sowing date, variety and fungicide was also significant, suggesting that the relationship between variety and fungicide also differed by sowing date (Table 26). This was because when comparing the untreated values, the susceptible and moderately susceptible varieties had significantly higher septoria severity when sown mid-September compared to mid-October, whereas for the moderately resistant varieties septoria severity was comparable across sowing dates. This meant that when sown mid-

September, there was a significant reduction in septoria severity up to a medium input programme in the susceptible varieties, and a low input programme in the moderately susceptible varieties, whereas for the moderately resistant group there was no significant differences between the four fungicide programmes. When sown mid-October, there was no significant benefit from applying above a low input strategy for the susceptible varieties, whereas for both the moderately susceptible and moderately resistant varieties there was no significant difference between any of the fungicide programmes (Figure 19). However, the interaction between site, sowing date, variety and fungicide was also statistically significant, suggesting that the relationship between variety and fungicide was not consistent across sites (Appendix 11).

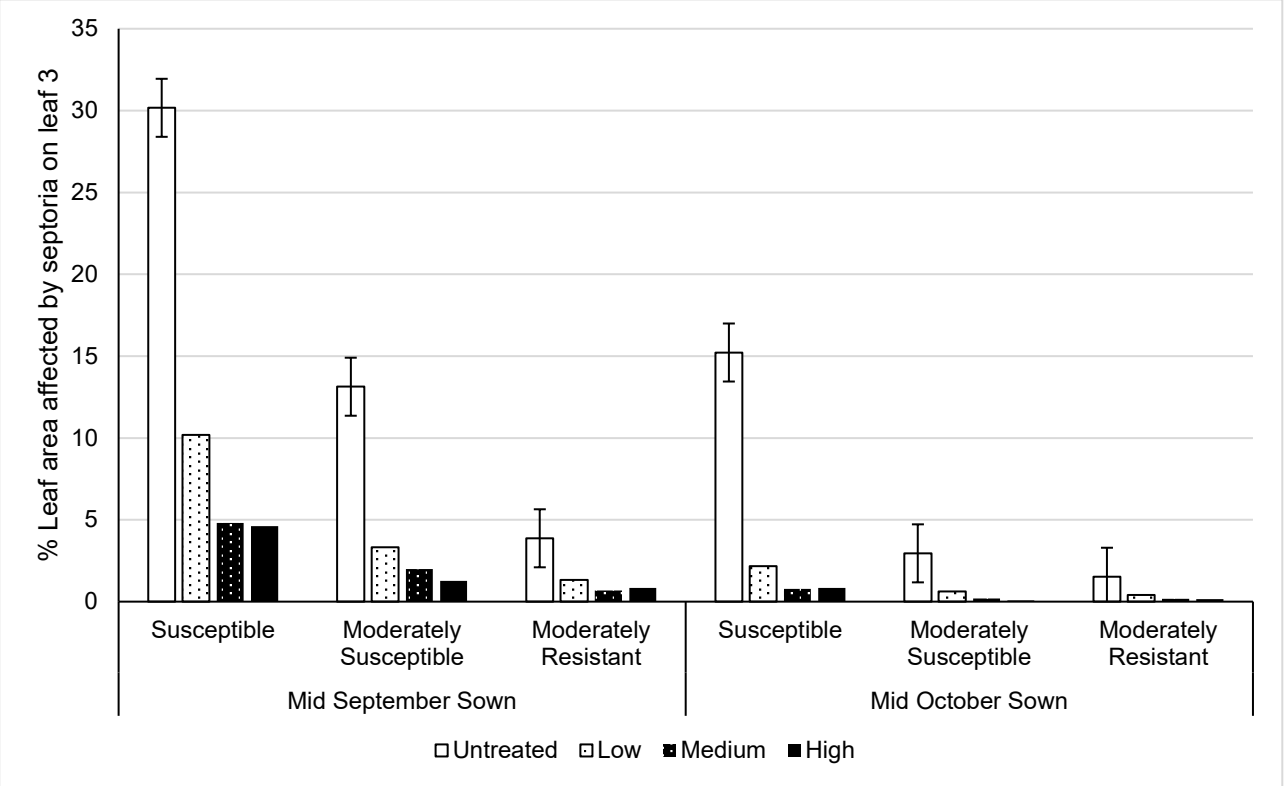

Figure 19: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks, for the interaction of sowing date, variety and fungicide in 2019, across sites 19 and 21. Error bars show the LSD for the interaction between sowing date, variety and fungicide.

T2 + 6-8 weeks disease assessment

In 2019, of the 4 trial sites, the highest disease pressure on leaf 2, was seen at site 22 with an average septoria severity of 30.07%. The lowest disease pressure was seen at site 20 with 0.5%.

Table 27: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 2 at T2 + 6-8 weeks in 2019.

Factor	P Value
Site	<.001
Sowing	0.003
Site.Sowing	0.003
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Site.Sowing.Variety	0.04
Site.Sowing.Fungicide	0.01
Site.Variety.Fungicide	0.015
Site.Sowing.Variety.Fungicide	0.049

Sowing date, variety and fungicide were also found to be significant factors affecting septoria severity (Table 27). On average, sowing early resulted in greater septoria severity than when sowing late, with an average severity of 16.23% compared to 11.17%. When comparing the different varieties, the susceptible group had significantly more disease than the moderately susceptible and moderately resistant which were statistically comparable (Table 28).

At this assessment, the interaction between variety and fungicide, and sowing date, variety and fungicide was not found to be significant. Therefore suggesting that, on this occasion, the response to fungicide was the same across all varieties and sowing dates (Figure 20). On average, septoria severity significantly decreased between the untreated and low input strategy and the low and medium input strategy, but there was no further significant reduction from the high input strategy (Table 28). However, the interaction between site and variety and site and fungicide was significant suggesting that the response to variety and fungicide was not consistent across sites (Appendix 12).

Table 28: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the variety and fungicide interaction in 2019, across sites 19, 20, 21 and 22.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	33.99	22.00	10.24	7.83	18.52
Moderately Susceptible	26.43	13.71	4.98	3.49	12.15
Moderately Resistant	24.62	9.33	3.90	3.84	10.42
Average	28.35	15.01	6.37	5.05	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	0.142		
LSD	2.077	2.398	4.153		

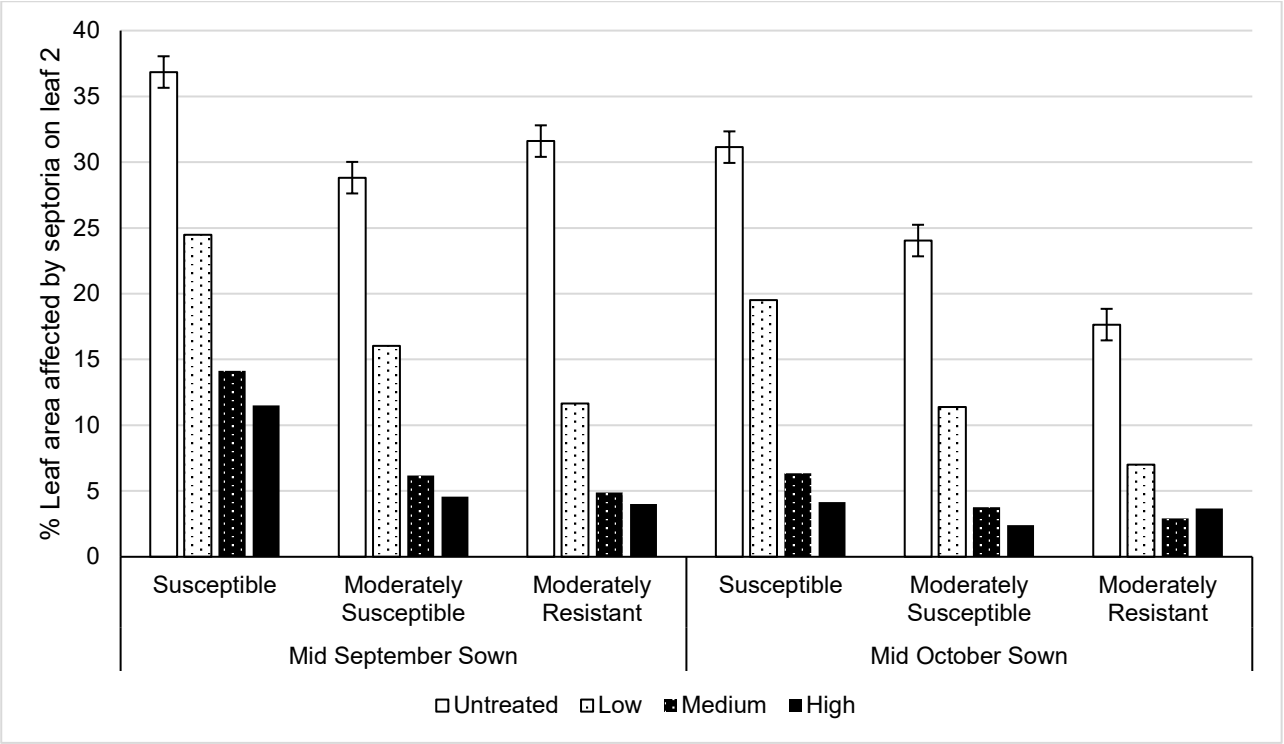

Figure 20: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks, for the interaction of sowing date, variety and fungicide in 2019, across sites 19, 20, 21 and 22. Error bars show the LSD for fungicides.

Yield

In 2019, yield varied by site ranging from 11.64t/ha (site 21) to 10.39t/ha (site 19).

Table 29: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for yield in 2019.

Factor	P Value
Site	<.001
Sowing	<.001
Site.Sowing	0.002
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Sowing.Fungicide	0.009
Site.Variety.Fungicide	<.001

Sowing date, variety and fungicide were also found to be significant factors affecting yield (Table 29). Later sowings achieved higher yields than early sowings (Figure 21) with an average of 10.94t/ha compared to 10.58t/ha. When comparing the different varieties, the moderately resistant group achieved significantly higher yields than the susceptible and moderately susceptible, which were statistically comparable (Table 30).

The interaction between variety and fungicide was also significant, suggesting that the effect of fungicide differed by variety (Table 29). For the susceptible varieties, yield significantly increased up to a medium input fungicide programme. For the moderately susceptible group, yield significantly increased between the untreated and low input programme, the low and medium input programmes were statistically comparable, but yield did significantly increase between the low and high input programme. However, for the moderately resistant varieties there was no significant benefit from applying more than a low input programme (Table 30). The interaction between site, variety and fungicide was also statistically significant suggesting that the relationship between variety and fungicide was not consistent across sites (Appendix 13).

Table 30: Average yield (t/ha) for the variety and fungicide interaction in 2019, across sites 19, 20, 21 and 22.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	9.01	10.47	11.11	11.27	10.47
Moderately Susceptible	9.77	10.61	10.79	11.03	10.55
Moderately Resistant	10.51	11.4	11.66	11.51	11.27
Average	9.76	10.83	11.19	11.27	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.150	0.173	0.300		

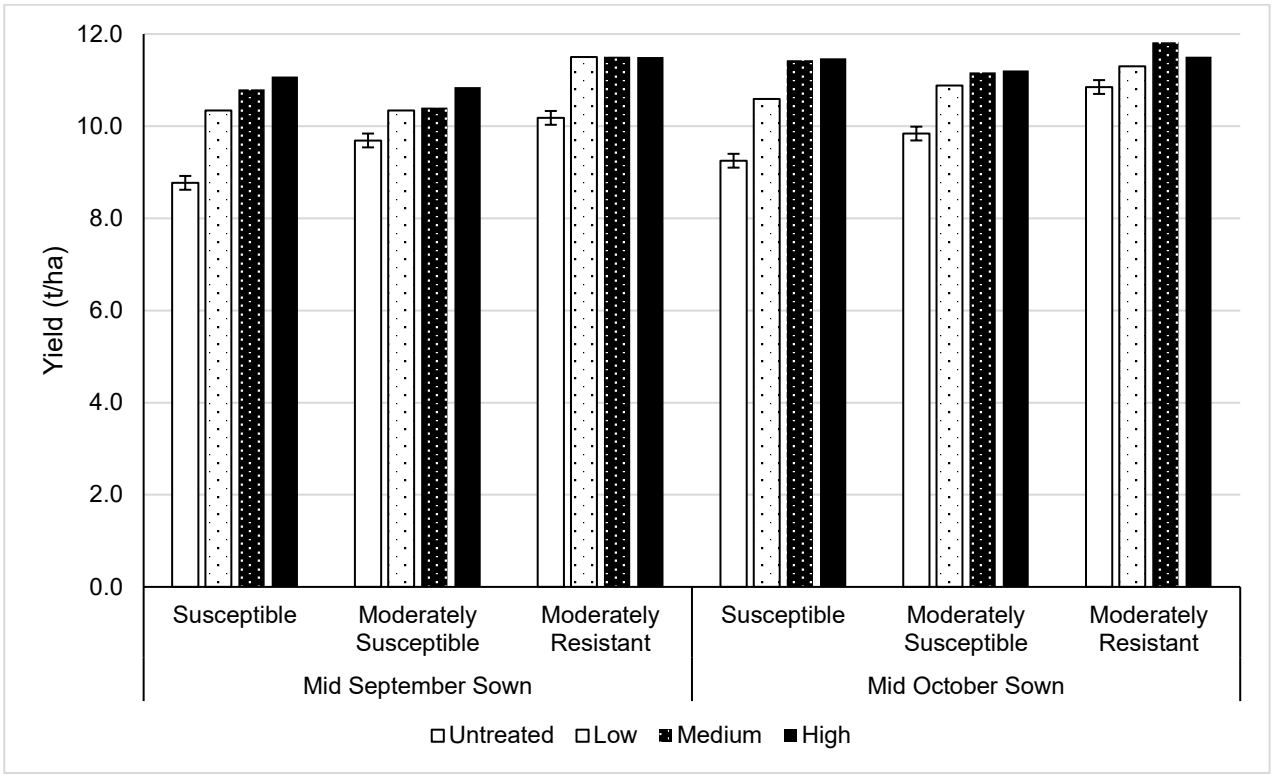

Figure 21: Average yield (t/ha), for the interaction of sowing date, variety and fungicide in 2019, across sites 19, 20, 21 and 22. Error bars show the LSD for the interaction between variety and fungicide.

Specific weight

In 2019, of the 3 sites that used the same varieties, site 20 had the highest specific weight, with an average of 74.73kg/hl, and site 21 the lowest with 70.28kg/hl.

Table 31: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for specific weight in 2019.

Factor	P Value
Site	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Sowing.Variety	0.049
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	0.003
Site.Variety.Fungicide	0.001

Variety and fungicide were also found to be significant factors affecting specific weight (Table 31). When comparing the different varieties, there were significant differences in specific weight between all three. Graham (moderately resistant) had the highest value and Santiago (susceptible) the lowest (Table 32).

The interaction between variety and fungicide was also significant, suggesting that the effect of fungicide differed by variety (Table 31). For both Santiago and Hardwick, specific weight significantly increased in the low input fungicide programme compared to the untreated, but there was no further benefit from the medium or high input programmes. Whereas for Graham, there was no significant differences between any of the fungicide programmes (Table 32, Figure 22). However, the interaction between site, variety and fungicide was also significant suggesting that the relationship between variety and fungicide differed by site (Appendix 14).

Table 32: Average specific weight (kg/hl) for the variety and fungicide interaction in 2019, across sites 19, 20, and 21.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Santiago	67.19	70.05	70.34	70.47	69.51
Hardwicke	71.55	72.72	72.96	73.15	72.59
Graham	73.38	73.44	73.93	73.46	73.55
Average	70.70	72.07	72.41	72.36	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.315	0.364	0.630		

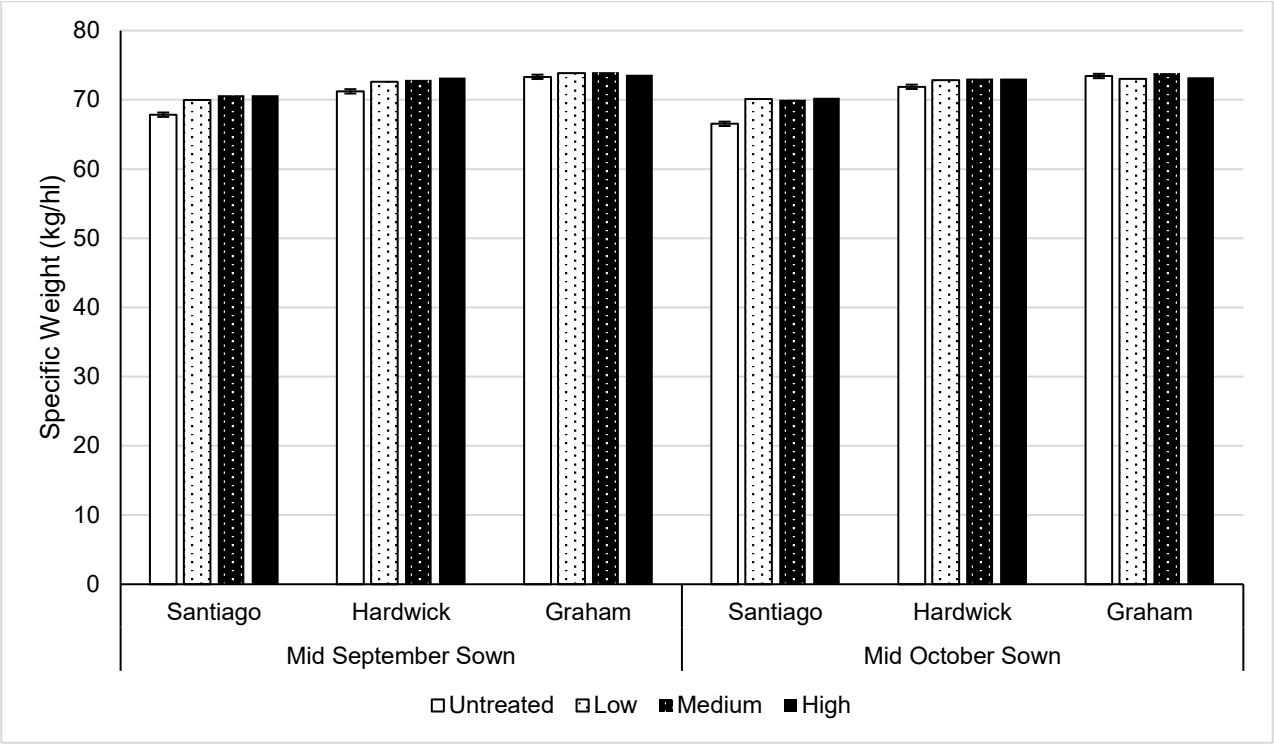

Figure 22: Average specific weight, for the interaction of sowing date, variety and fungicide in 2019, across sites 19, 20, and 21. Error bars show the LSD for the interaction between variety and fungicide.

4.2.5. 2020 season

In 2020, the field experiments endured some extreme meteorological conditions. High autumn rainfall made establishing trials very difficult. The spring by contrast was very dry with below average rainfall across most of the UK in March, April and May, limiting disease progress and in some cases inducing drought. Rainfall in June was closer to average with above average rainfall received in the west (Figure 2, Figure 3). As a result of the difficult drilling conditions, late sown plots at site 23 weren't drilled until the 23rd March and, consequently, only the KWS Firefly vernalised. Therefore, as no late sown data could be collected, this site has been excluded from all analysis.

T2 + 2-3 weeks disease assessment

The disease pressure at each site was low in 2020, with the highest disease pressure seen at site 24, with an average septoria severity of 4.08% on leaf 3, compared to 0.49% at site 25.

Table 33: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks in 2020.

Factor	P Value
Site	0.012
Site.Sowing	0.029
Variety	<.001
Fungicide	<.001
Site.Variety	0.001
Sowing.Variety	0.008
Site.Fungicide	<.001
Variety.Fungicide	0.008
Site.Sowing.Variety	0.023
Site.Sowing.Fungicide	0.029
Site.Variety.Fungicide	0.01
Sowing.Variety.Fungicide	0.004

In addition to site, variety and fungicide were also found to be significant factors affecting septoria severity at this time (Table 33). The varietal differences reflected variety resistance ratings as the susceptible group had the highest disease severity on average and the moderately resistant the lowest.

The interaction between variety and fungicide indicated that the effect of fungicide differed by variety, but this was also affected by sowing date, in a three-way interaction (Table 33). This was because when comparing the untreated, the susceptible variety sown mid-September had significantly higher septoria severity than any of the other untreated situations, whether sown in mid-September or mid-October. This meant that in the susceptible variety sown mid-September, there was a significant benefit in disease control from applying up to a medium input fungicide programme. In both the moderately susceptible and moderately resistant varieties sown mid-September, there was no significant differences between any of the fungicide programmes. When the susceptible and moderately resistant variety were sown in mid-October, there were also no significant differences between the fungicide programmes. However, in the moderately susceptible variety sown mid-October, there was a significant difference between the untreated and high input programme (Figure 23).

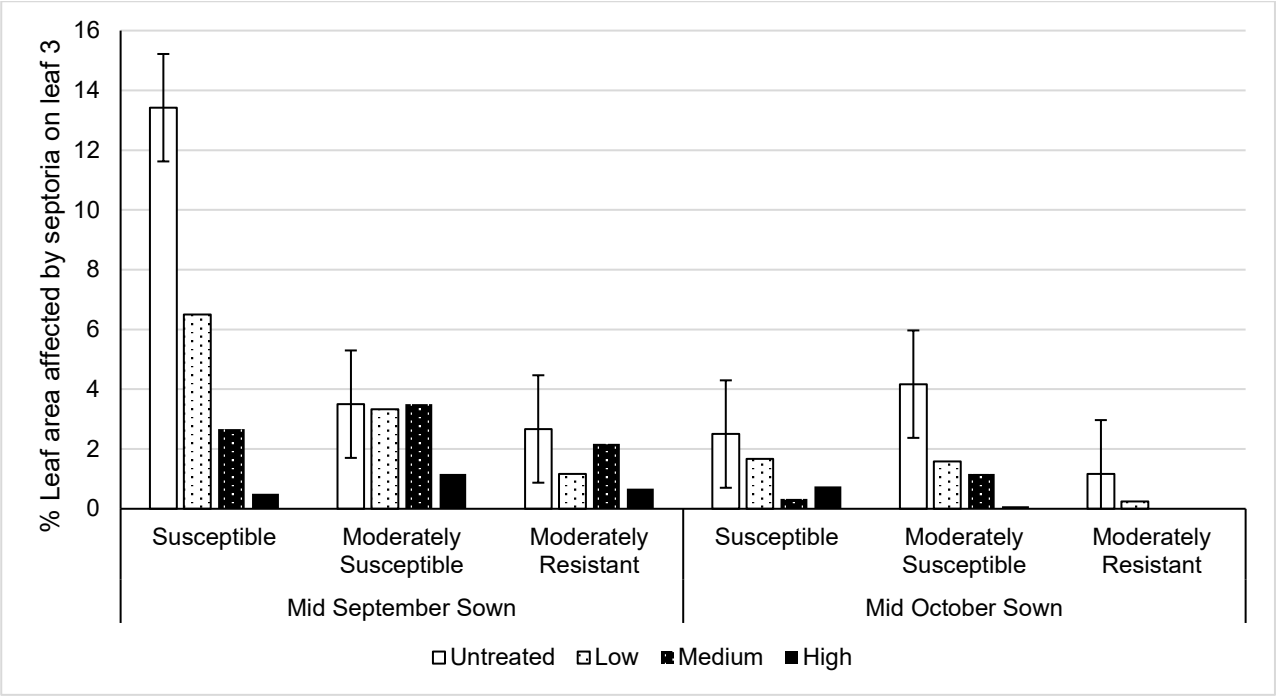

Figure 23: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks, for the interaction of sowing date, variety and fungicide in 2020, across sites 24 and 25. Error bars show the LSD for the interaction between sowing date, variety and fungicide.

T2 + 6-8 weeks disease assessment

By T2 + 6-8 weeks, septoria severity had increased, severity differed by site averaging 22.34% on leaf 2 at site 24, and 3.22% at site 25.

Table 34: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 2 at T2 + 6-8 weeks in 2020.

Factor	P Value
Site	<.001
Sowing	0.017
Site.Sowing	0.039
Variety	0.029
Fungicide	<.001
Site.Fungicide	<.001

Sowing date, variety and fungicide were also found to be significant as a single factor (Table 34). On average, the early sowing had higher septoria severity than the late sowing (Figure 24) with 15.44% compared to 10.12% severity on average. When comparing varieties, the susceptible variety group had significantly higher septoria severity than the moderately resistant group (Table 35).

On this occasion there was no significant interactions between variety and fungicide. Therefore, suggesting that the response to fungicides was the same across all three varieties. On average each level of fungicide input achieved a significant reduction in septoria severity, from untreated to

low, low to medium and medium to high (Table 35). However, the interaction between site and fungicide was also significant, suggesting that this response was not consistent across sites (Appendix 15).

Table 35: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the variety and fungicide interaction in 2020, across sites 24 and 25.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	30.01	13.33	10.75	4.29	14.60
Moderately Susceptible	23.28	15.63	10.08	4.83	13.46
Moderately Resistant	16.31	13.33	7.75	3.75	10.28
Average	23.20	14.10	9.53	4.29	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	0.029	<.001	0.082		
LSD	3.260	3.765	6.521		

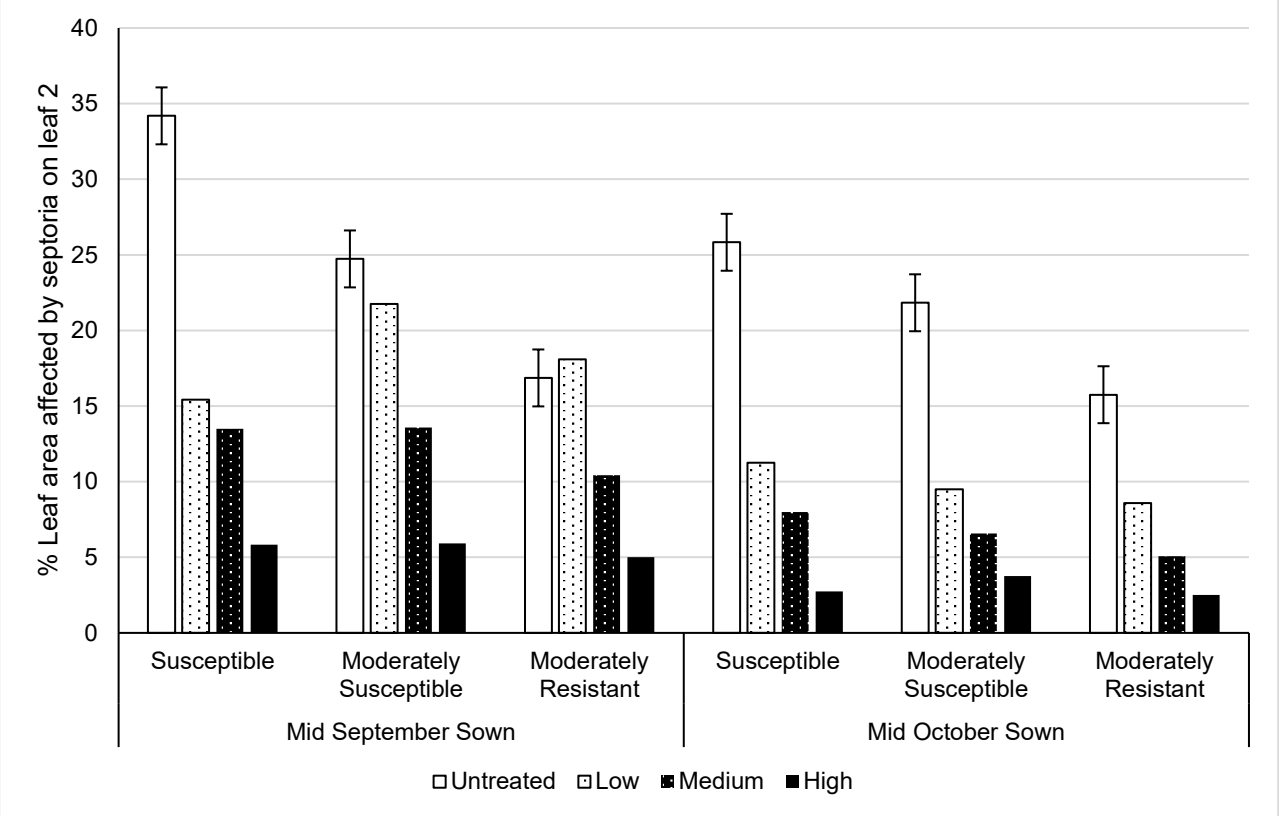

Figure 24: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks, for the interaction of sowing date, variety and fungicide in 2020, across sites 24 and 25. Error bars show the LSD for fungicide.

Yield

The average yield achieved by each site in 2020 was very similar with 10.89t/ha at site 24 and 10.26t/ha at site 25.

Table 36: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for yield in 2020.

Factor	P Value
Site.Sowing	0.01
Variety	<.001
Fungicide	<.001
Sowing.Variety	<.001
Site.Sowing.Variety	0.045

Variety and fungicide were found to be significant factors affecting the yield results (Table 36). When comparing the different varieties, on average the susceptible variety achieved the lowest yield, significantly lower than the moderately susceptible and moderately resistant which were comparable (Table 37).

The yield response to fungicides in 2020 was consistent across varieties. On average, yield significantly increased between the untreated and low input programme, the low input and medium input were comparable, but the high input programme provided a further benefit above that of the medium input programme (Table 37).

Table 37: Average yield (t/ha) for the variety and fungicide interaction in 2020, across sites 24 and 25.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	9.64	10.44	10.57	10.90	10.39
Moderately Susceptible	9.70	10.84	10.89	11.20	10.66
Moderately Resistant	10.00	10.77	10.88	11.13	10.70
Average	9.78	10.68	10.78	11.08	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	0.663		
LSD	0.164	0.189	0.328		

The interaction between sowing date, variety and fungicide was not significant suggesting that the response to fungicide was consistent across variety and sowing dates (Figure 25).

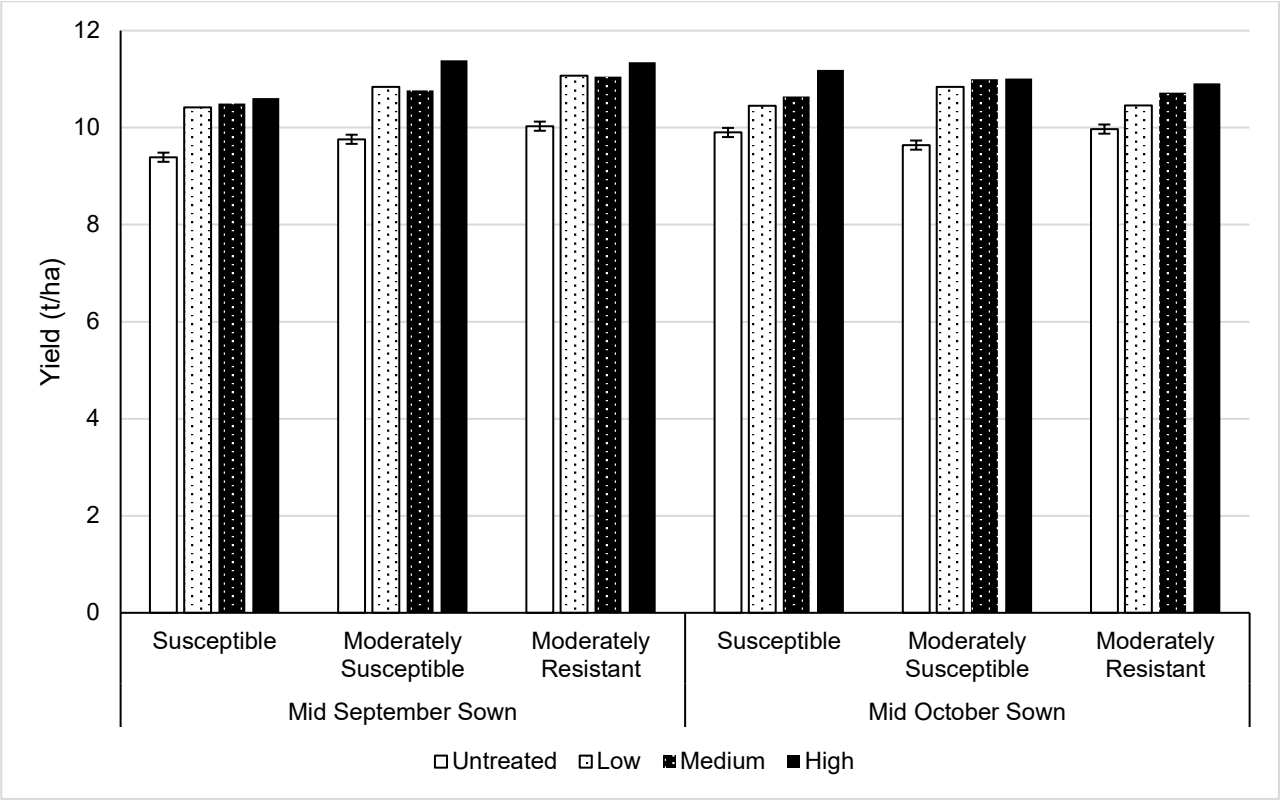

Figure 25: Average yield (t/ha), for the interaction of sowing date, variety and fungicide in 2020, across sites 24 and 25. Error bars show the LSD for fungicide.

Specific weight

Specific weight differed by site, site 24 had the highest values with an average of 74.75kg/hl, compared to 68.38kg/hl at site 25.

Table 38: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for specific weight in 2020.

Factor	P Value
Site	0.002
Site.Sowing	0.007
Site.Variety	0.048

In 2020 there was no significant differences in specific weight by sowing date, variety or fungicide as differences between treatments were small, possibly due to the very dry conditions (Figure 26).

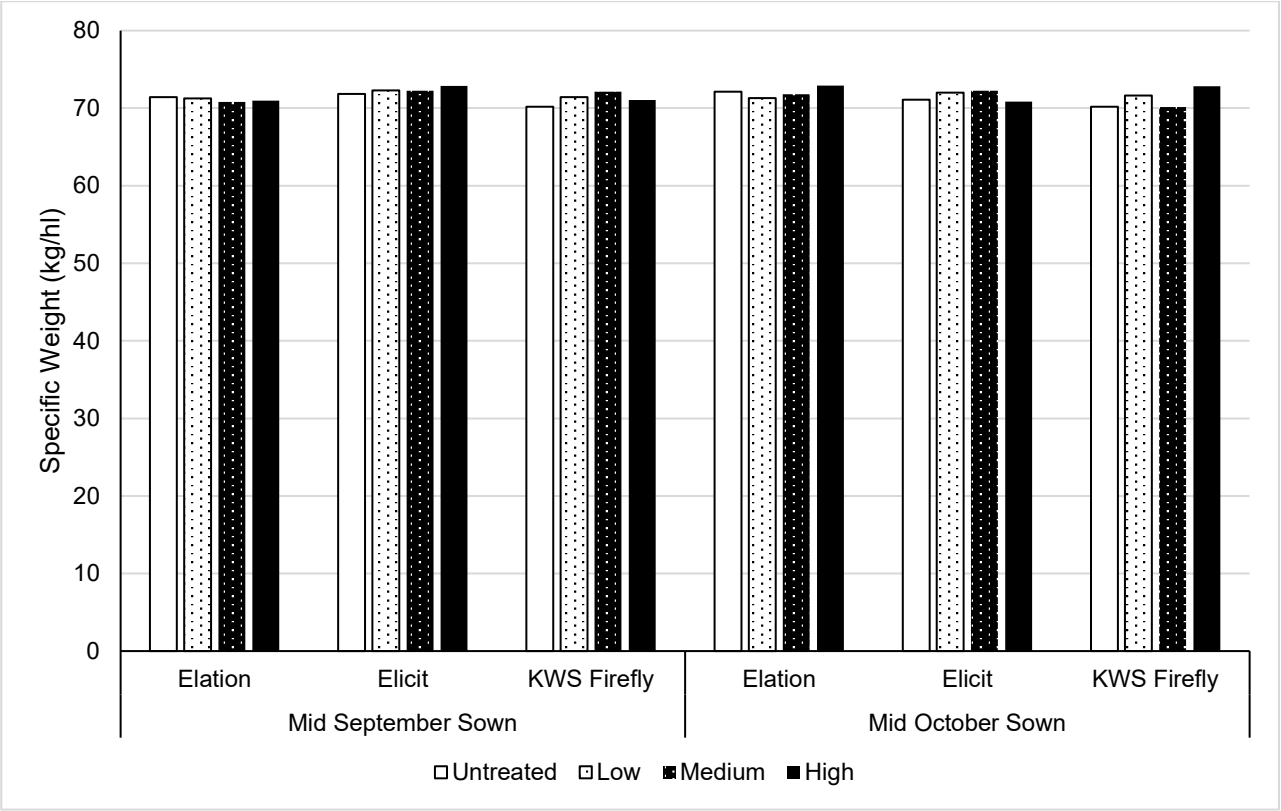

Figure 26: Average specific weight, for the interaction of sowing date, variety and fungicide in 2020, across sites 24 and 25.

4.3. Analysis across all sites and seasons

All sites and seasons have been combined to show the average response. For 2016 to 2018 only data from the high seed rates was used to create a balanced design.

4.3.1. T2 + 2-3 weeks disease assessment

Across all seasons, the highest disease pressure at the first assessment, was at site 13 with an average septoria severity of 19.39%, the lowest disease pressure was at site 21 with an average of 0.28%.

Table 39: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks across all seasons.

Factor	P Value
Site	<.001
Sowing	<.001
Site.Sowing	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001
Site.Sowing.Variety.Fungicide	<.001

Sowing date, variety and fungicide were also found to be significant factors (Table 39). On average early sowing had higher disease severity than late sowing (Figure 27) with an average of 6.33% compared to 3.44%. When comparing the different varieties, each variety was significantly different, and reflected the resistance ratings of the groups (Table 40).

The interaction between variety and fungicide was also found to be statistically significant, suggesting that the response to fungicide varied by variety (Table 39). In the susceptible varieties, there was a significant reduction in septoria severity from applying up to a high input programme. However, for the moderately susceptible varieties the low and medium input programme performed comparably, but there was a significant benefit from the high input programme compared to the low. In the resistant varieties, there was no further benefit from applying more than a low input programme (Table 40). The interaction between site, variety and fungicide indicated that the relationship between variety and fungicide was not consistent across sites (Appendix 16).

Table 40: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the variety and fungicide interaction across sites 1 to 10, 12 to 15, 17 to 19, 21, 24 and 25.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	17.19	5.19	4.10	2.63	7.28
Moderately Susceptible	12.27	3.25	2.44	1.74	4.92
Moderately Resistant	6.18	1.54	1.31	0.77	2.45
Average	11.88	3.33	2.61	1.71	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.504	0.582	1.009		

The interaction between sowing date, variety and fungicide was not found to be significant, suggesting that the relationship between variety and fungicide was consistent across sowing dates. However, when sowing in mid-October, the level of disease in the untreated of each variety was lower than when sown mid-September. As a result, a moderately susceptible variety sown mid-October is comparable to a moderately resistant variety sown mid-September (Figure 27).

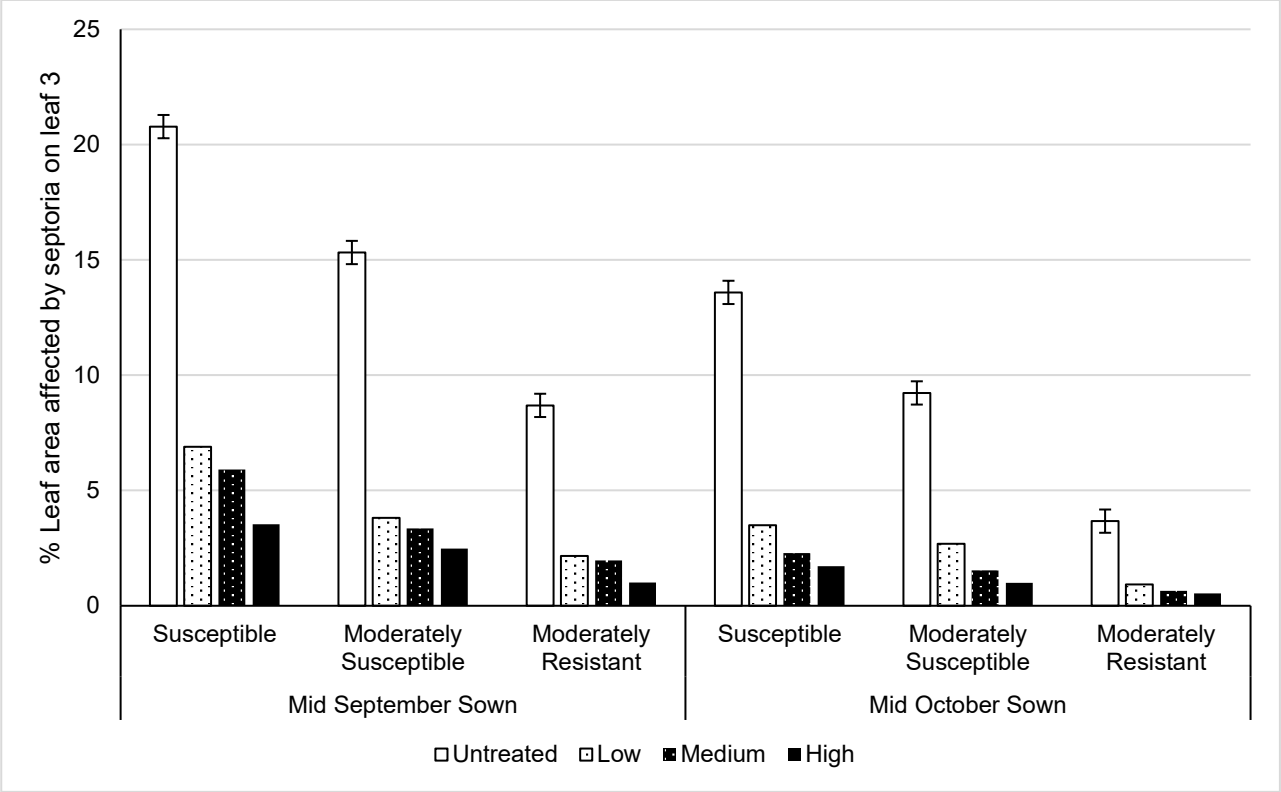

Figure 27: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks, for the interaction of sowing date, variety and fungicide across sites 1 to 10, 12 to 15, 17 to 19, 21, 24 and 25. Error bars show the LSD for the interaction between variety and fungicide.

4.3.2. T2 + 6-8 weeks disease assessment

Across all seasons, the highest disease pressure at the second assessment was at site 22, with an average septoria severity of 30.07%, the lowest disease pressure was at site 16, with an average of 0.19%.

Table 41: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for Septoria severity on leaf 2 at T2 + 6-8 weeks across all seasons.

Factor	P Value
Site	<.001
Sowing	<.001
Site.Sowing	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001
Sowing.Variety.Fungicide	0.006
Site.Sowing.Variety.Fungicide	0.002

Sowing date, variety and fungicide were also found to significantly affect septoria severity (Table 41). On average, early sowing had higher disease severity with an average of 10.95%, compared to 8.72% when sown late. When comparing the different varieties, all three were significantly different from one another, with disease severity increasing with varietal susceptibility.

The response to fungicide differed by variety. However, the interaction between sowing date, variety and fungicide was also significant indicating that the relationship between variety and fungicide varied by sowing date (Table 41). Comparisons of the untreated indicate both the susceptible and moderately susceptible varieties showed no significant difference in septoria severity across sowing dates. However, the level of disease in the moderately resistant varieties did significantly decrease when sown mid-October compared to mid-September. When sown mid-September there was a significant benefit in disease control up to a medium input fungicide programme on the susceptible varieties, although the high input programme achieved a further reduction compared to the medium, this difference wasn't quite significant. For the moderately susceptible varieties, there was a significant reduction in septoria severity up to a high input programme. Whereas for the moderately resistant group, there was no further benefit from applying more than a medium input programme. When sown mid-October, there was a significant benefit on disease control from applying up to a high input programme in the susceptible variety and medium input programme in the moderately susceptible variety. In the moderately resistant variety, the difference between the low and medium input programmes wasn't quite significant, but there was a significant difference between the low and high input programmes (Figure 28). However, the interaction between site, sowing date, variety, and fungicide was also significant, indicating that this relationship varied by site (Appendix 17).

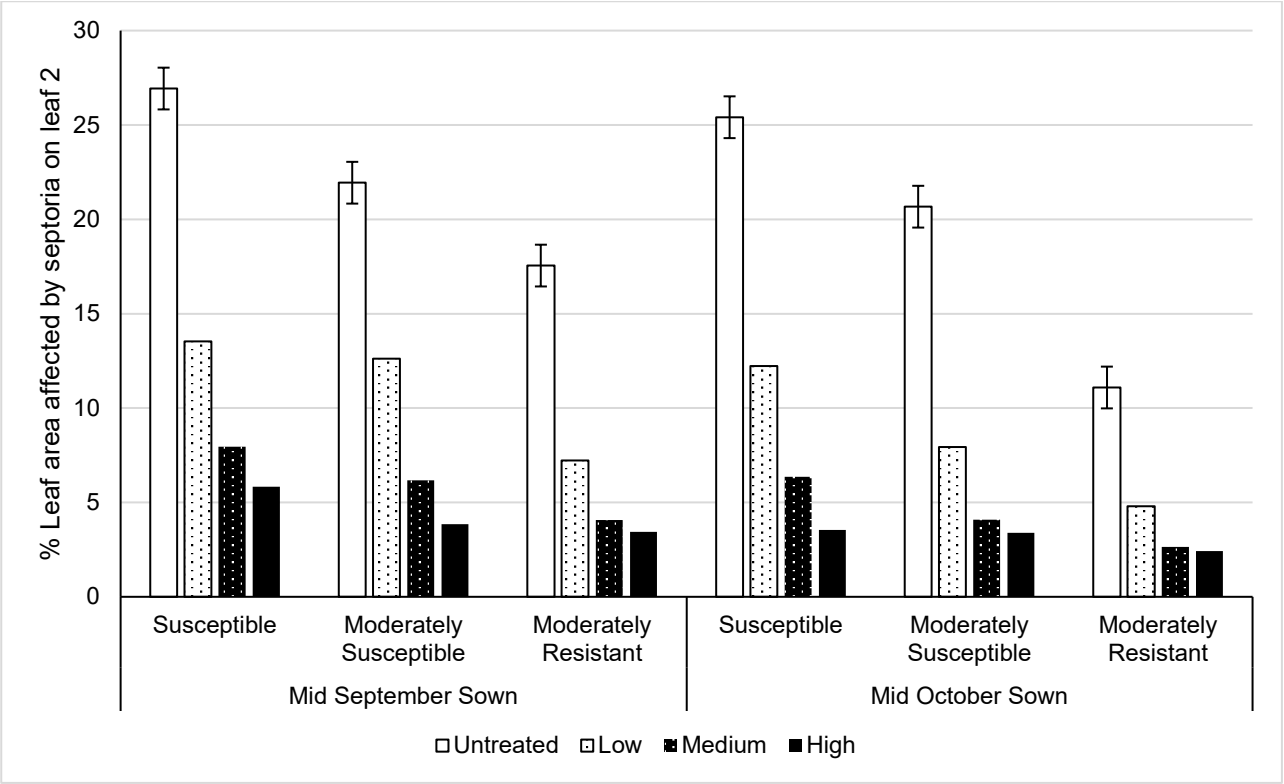

Figure 28: Average septoria severity on leaf 2 (%) at T2 + 6-8 weeks, for the interaction of sowing date, variety and fungicide across sites 1 to 6, 8, 9, 11, 12, 14 to 16, 18 to 22, 24 and 25. Error bars show the LSD for the interaction between sowing date, variety and fungicide.

4.3.3. Yield

Across all seasons, the highest yield was achieved at site 18 with an average of 12.20t/ha, and the lowest was at site 2 with 5.18t/ha.

Table 42: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for yield across all seasons.

Factor	P Value
Site	<.001
Sowing	0.048
Site.Sowing	0.009
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001

In addition to site, sowing date, variety and fungicide were also found to be significant as a single factor (Table 42). On average, late sowing achieved higher yields than early with 10.29t/ha

compared to 10.12t/ha. When comparing the different varieties, the moderately resistant variety achieved the highest yield when averaged across all fungicide treatments and sowing dates, significantly higher than both the susceptible and moderately susceptible groups which were comparable (Table 43).

The yield response to fungicide differed by variety (Table 42). In the susceptible variety there was a benefit in yield from applying up to a high input fungicide programme, however the difference between the medium and high input programmes wasn't quite statistically significant. In the moderately susceptible variety, there was a significant benefit in yield from applying up to a high input programme, however in the moderately resistant variety there was no significant benefit above the low input programme (Table 43). The interaction between site, variety and fungicide was also significant, suggesting that the relationship between variety and fungicide differed by site (Appendix 18).

Table 43: Average yield (t/ha) for the variety and fungicide interaction across all seasons.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	9.10	10.17	10.69	10.81	10.19
Moderately Susceptible	9.32	10.20	10.42	10.58	10.13
Moderately Resistant	9.68	10.45	10.47	10.58	10.30
Average	9.37	10.27	10.53	10.66	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.073	0.085	0.146		

The relationship between variety and fungicide was consistent across sowing dates (Figure 29). However, when the data is considered as yield response compared to the untreated (Figure 30), it is clear that the susceptible varieties sown mid-September achieved the largest yield response to fungicides, and the moderately resistant varieties sown mid-October the smallest. Furthermore, the difference between the medium and high input strategy for the susceptible and moderately susceptible varieties is larger when sown mid-September compared to mid-October.

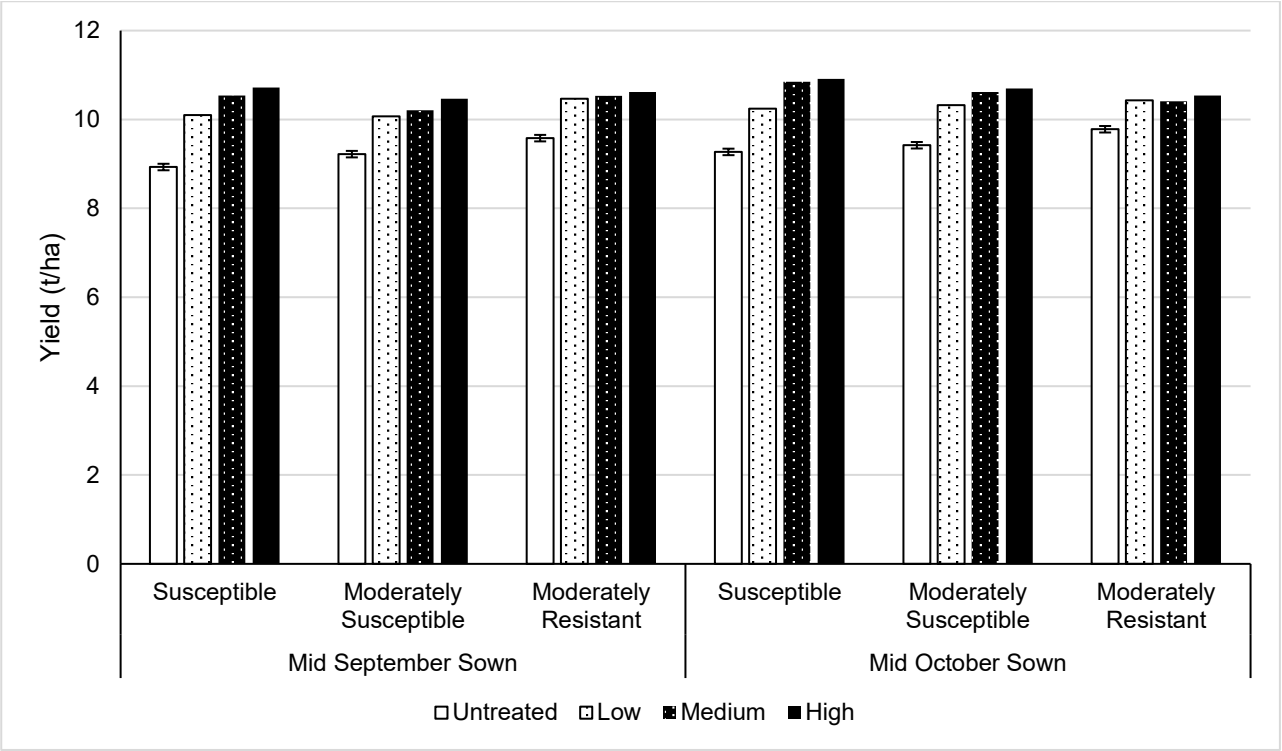

Figure 29: Average yield (t/ha), for the interaction of sowing date, variety and fungicide across sites 1 to 3, 6 to 16, 18 to 22, 24 and 25. Error bars show the LSD for the interaction between variety and fungicide.

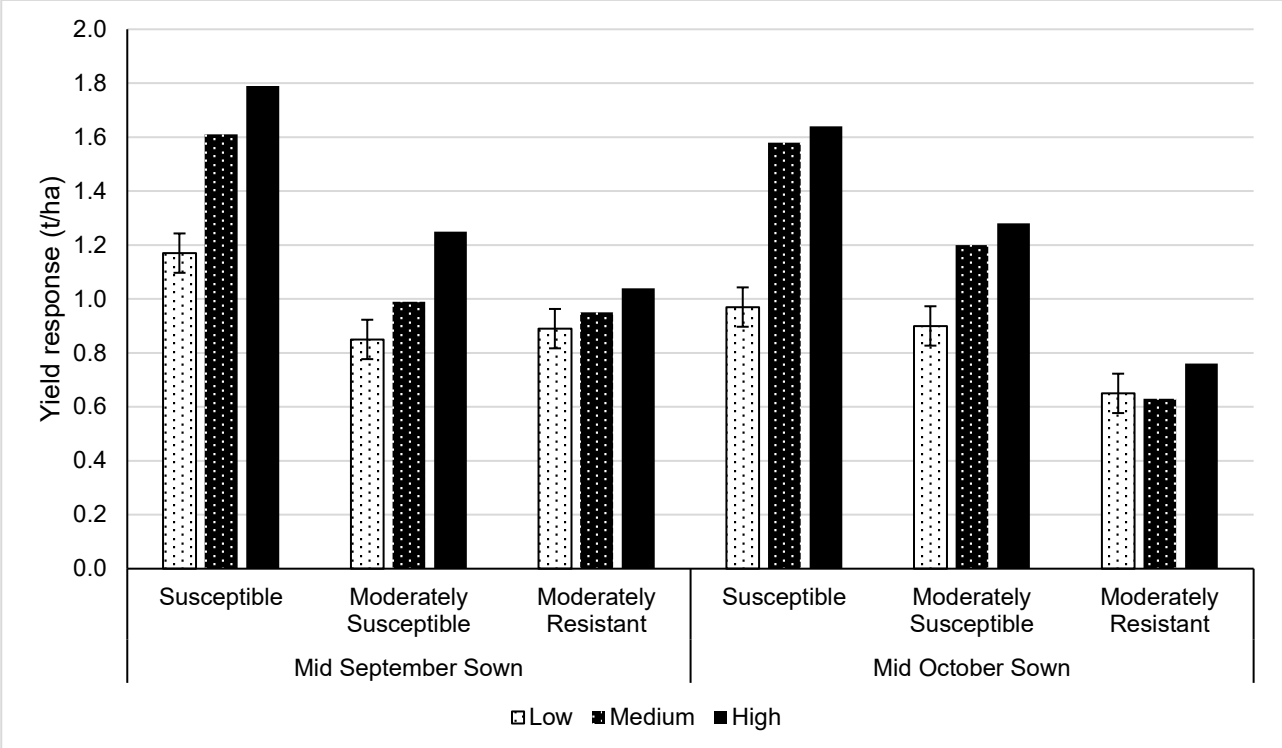

Figure 30: Average yield response (t/ha), for the interaction of sowing date, variety and fungicide across sites 1 to 3, 6 to 16, 18 to 22, 24 and 25. Error bars show the LSD for the interaction between variety and fungicide.

4.3.4. Output

To summarise the results from an economic perspective, the average yield results have been converted to output using a grain price of £165/t (Table 44). This indicates that, when left untreated, output increases as you move from a susceptible variety to a moderately resistant variety, as you would expect given the higher septoria resistance ratings. However, when treated with a high input programme the differences between the three varieties are much smaller, ranging from £1728/ha in the moderately susceptible variety to £1769/ha in the susceptible variety when sown mid-September, and £1739/ha in the moderately resistant variety to £1800/ha in the susceptible variety when sown mid-October. These differences in output between the different variety groups under the high input programme are driven by the yield potential of the chosen varieties. Santiago, which dominates the susceptible variety group, is a high yielding variety and therefore the susceptible group has achieved the highest output in this project. But there are some high yielding varieties with high resistance ratings against septoria, so this will not always be the case.

When comparing the additional output each fungicide programme achieved above that of the untreated (Table 45), it's clear that applying a low input fungicide programme increased output in all situations with an increase of at least £100/ha across all sowing dates and varieties, covering the cost of a low input strategy. However, the additional output from the medium and high input programmes varied substantially by variety. In the susceptible varieties an additional £100/ha was achieved between a low and high input programme irrespective of sowing date. However, in the moderately resistant group, the additional output from medium and high input programmes is very small, with an increase of only £25 when sown mid-September and £18 when sown mid-October between the low and high input programmes.

Margin over fungicide costs have not been calculated here, as it would be a misrepresentation of the results. The total cost of each fungicide programme in this project does not accurately represent the cost of a typical low, medium, and high input strategy. The low input programme was based on chlorothalonil which was very cost effective but is no longer available. Therefore, the cost now to growers of a low input programme to achieve an equivalent level of control will be higher. Furthermore, as the programmes were designed to build incrementally and hence show what each active adds to disease control and yield, the high input strategy will be more expensive, as an azole and SDHI have been applied as two separate products instead of a formulated mix.

Table 44: Average output (£/ha) for each treatment, before accounting for the cost of fungicides, using data from across all sites and seasons.

		Fungicide			
Sowing Date	**Variety**	**Untreated**	**Low**	**Medium**	**High**
Mid September Sown	**Susceptible**	1473	1667	1739	1769
	Moderately Susceptible	1521	1662	1685	1728
	Moderately Resistant	1581	1728	1737	1752
Mid October Sown	**Susceptible**	1530	1690	1790	1800
	Moderately Susceptible	1554	1703	1752	1766
	Moderately Resistant	1614	1721	1718	1739

Table 45: Additional output (£/ha) from the low, medium and high input fungicide programmes compared to the untreated, before accounting for the cost of fungicides, using data from across all sites and seasons.

		Fungicide		
Sowing Date	**Variety**	**Low**	**Medium**	**High**
Mid September Sown	**Susceptible**	193	266	295
	Moderately Susceptible	140	163	206
	Moderately Resistant	147	157	172
Mid October Sown	**Susceptible**	160	261	271
	Moderately Susceptible	149	198	211
	Moderately Resistant	107	104	125

4.4. Analysis by disease pressure

Trial sites were divided into three groups representing low, medium and high disease pressure. To categorise the sites, septoria severity data on leaf 1 at T2 + 6-8 weeks in the early sown, untreated, moderately susceptible variety was used. Sites were classed as low pressure if the severity on this leaf ranged from 0 to 5%, medium pressure, 6 to 15% and high, greater than 15% (Table 46). Sites 7, 10 and 17 could not be classified as there was no reliable assessment data at this timing. Site 23 was not included as there was no late sown data for this site.

Table 46: Total rainfall for the months of March to June at each trial site compared to the long term mean (LTM) for each region, and disease pressure group classification. For most sites the LTM uses data from the closest MET office weather station (MET Office, Historic Station Data 2021a), for the sites in Ireland, UCD and Teagasc provided the LTM from local weather stations. Values in bold are greater than the long term mean for that region.

Site Number	Site	Total Rainfall in March	Total Rainfall in April	Total Rainfall in May	Total Rainfall in June	Disease pressure group
1	RM 2016	**71.8**	43.8	32.8	**69.6**	Medium
7	RM 2017	50.1	7.4	55.4	24.7	-
13	RM 2018	**97.3**	**59.1**	**65.0**	16.0	High
19	RM 2019	42.6	**60.4**	49.8	**123.4**	High
23	RM 2020	27.4	30.2	1.6	**58.4**	-
	LTM 1991-2020	53.0	54.6	56.7	55.7	
2	TT 2016	**101.1**	**56.1**	21.1	**117.5**	Low
8	TT 2017	**36.7**	13.8	**79.5**	**80.4**	Medium
14	TT 2018	**61.6**	**67.8**	38.7	5.5	Low
	LTM 1991-2020	32.9	37.6	43.2	49.3	
3	NIAB 2016	34.6	39.4	43.2	31.2	High
9	NIAB 2017	33.5	7.1	41.6	20.3	Medium
15	NIAB 2018	**44.2**	43.2	32.3	0.8	Low
20	NIAB 2019	**69.0**	29.4	48.7	**103.5**	Low
24	NIAB 2020	**44.0**	47.0	3.8	42.2	High
	LTM 1991-2020	42.9	48.1	56.7	50.2	
4	SRUC 2016	31.0	**71.0**	27.0	60.0	Medium
10	SRUC 2017	36.6	11.6	20.6	**145.8**	-
16	SRUC 2018	**48.0**	**61.9**	19.9	**99.2**	Low
21	SRUC 2019	**55.4**	31.4	**62.4**	44.8	Low
25	SRUC 2020	**49.0**	1.2	34.2	**76.2**	Medium
	LTM 1991-2020	46.3	43.3	50.2	62.8	
5	Teagasc 2016	40.6	**64.3**	**61.6**	61.7	Low
11	Teagasc 2017	**66.6**	15.8	**81.8**	**91.0**	High
17	Teagasc 2018	**98.1**	**73.0**	24.3	5.2	-
22	Teagasc 2019	**122.9**	**72.5**	14.1	55.0	High
	LTM 1991-2020	61.2	59.7	57.1	63.7	
6	UCD 2016	38.7	**59.7**	**62.6**	**111.3**	High
12	UCD 2017	**65.9**	8.8	**67.1**	**91.8**	High
18	UCD 2018	**69.1**	**76.1**	16.8	18.5	Low
	LTM 1991-2020	50.7	51.9	59.1	62.5	
Average	LTM 1991-2020	47.8	49.2	53.9	57.4	

To directly compare rainfall across sites from different regions, an average of the long-term mean (LTM) across all regions was calculated (Table 46). The total rainfall at each site from March to June was then compared to the average LTM (Figure 31). This shows there was a good range of weather conditions across the sites included in this project, with about 50% of sites being below the average LTM and 50% above, generating different disease pressure scenarios. As expected, the high-pressure sites tended to be among those with the most rainfall, although there are a few exceptions.

However, as previously discussed, the rainfall in April, and May in particular, tended to be below or close to average across all 5 years of this project. Across all 25 sites, rainfall in May ranged from 1.6mm to 81.8mm, whereas in June, rainfall ranged from 0.8mm to 145.8mm. When comparing the total rainfall received at each site in April and May, key months for the spread of septoria within a crop, with the average LTM for April and May, most sites were below average with only 5 sites above (Figure 32).

Therefore, the disease pressure groups represent low, medium and high disease pressure within the context of this project. However, this dataset is lacking sites with high April and May rainfall, which may result in higher disease pressure than what was achieved within this project.

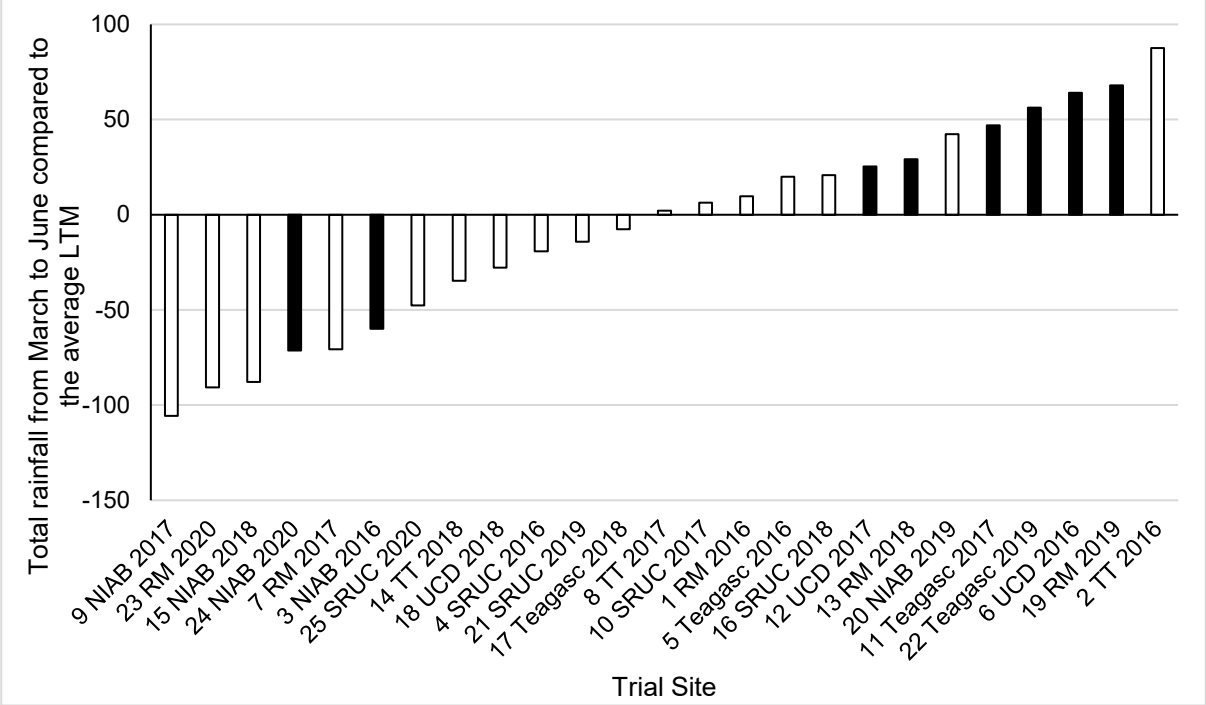

Figure 31: Total rainfall from March to June at each site compared to the average LTM. The black bars show the high-pressure sites.

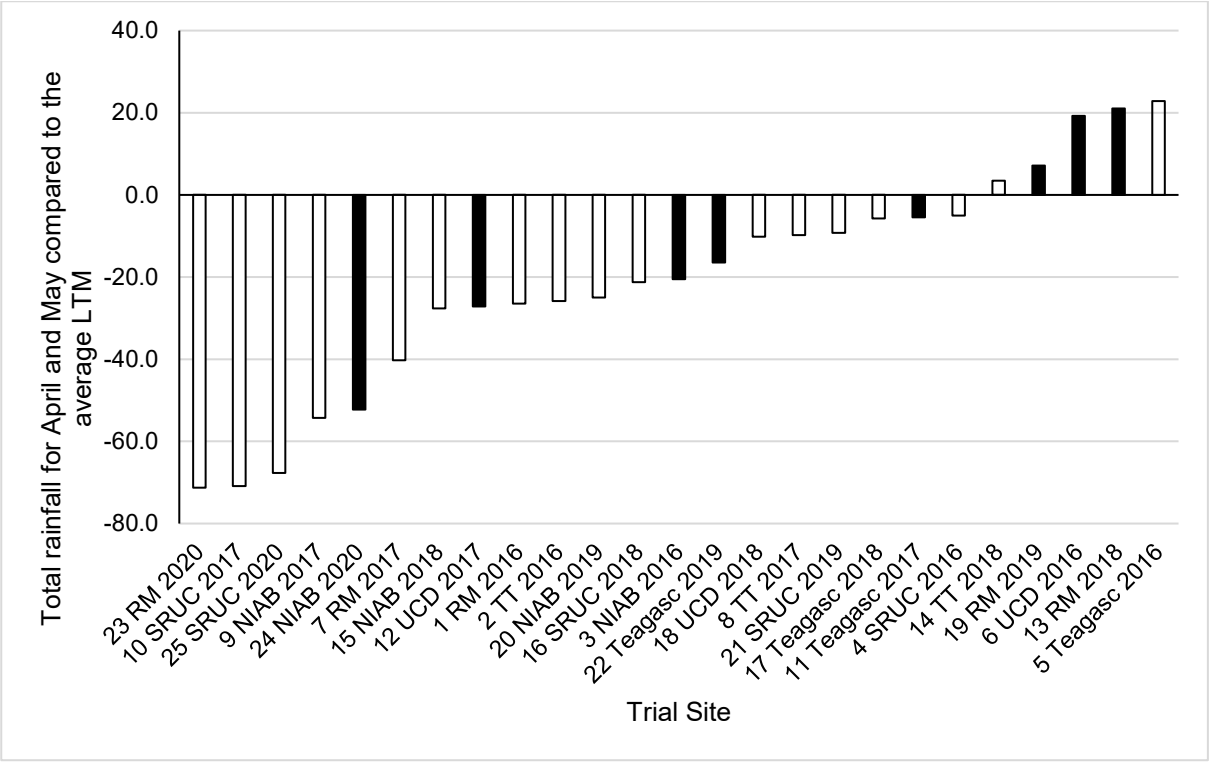

Figure 32: Total rainfall for April and May at each site compared to the average LTM. The black bars show the high-pressure sites.

4.4.1. Low disease pressure sites

T2 + 2-3 weeks disease assessment

The average septoria severity across all treatments varied significantly within the low-pressure sites, ranging from 0.28% at site 21 to 6.75% at site 18.

Table 47: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks in low pressure sites.

Factor	P Value
Site	<.001
Sowing	<.001
Site.Sowing	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	0.001
Site.Sowing.Fungicide	0.024

In addition to site differences, sowing date, variety and fungicide were also found to be significant factors affecting septoria at this time (Table 47). Despite the low disease pressure, early sowings had greater septoria severity than later sowings (Figure 33) with 3.45% compared to 2.02%. When comparing the different varieties, the moderately resistant group had the lowest septoria severity

on average, significantly lower than the susceptible and moderately susceptible varieties which were statistically comparable (Table 48).

The interaction between variety and fungicide was also found to be significant (Table 47). For the susceptible and moderately susceptible varieties, there was no significant benefit from applying above a low input programme. However, in the moderately resistant group, the level of disease in the untreated was very low, and therefore there was no significant differences between any of the fungicide programmes (Table 48).

Table 48: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the variety and fungicide interaction in low pressure sites, 2, 5, 14, 15, 18 and 21.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	7.90	2.56	1.40	1.54	3.35
Moderately Susceptible	6.40	2.97	1.77	2.63	3.44
Moderately Resistant	2.19	1.35	1.10	1.05	1.42
Average	5.49	2.30	1.42	1.74	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.623	0.719	1.246		

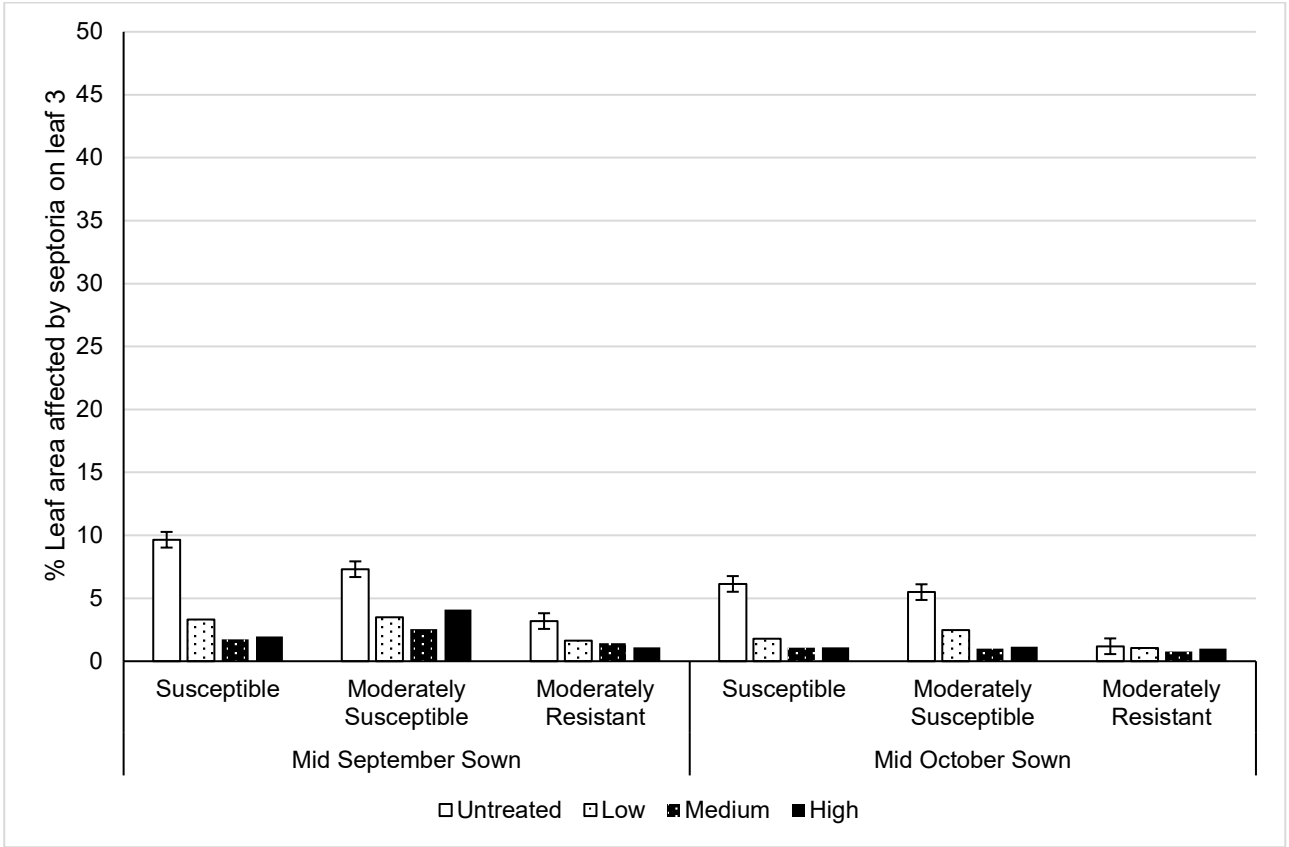

Figure 33: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks, for the interaction of sowing date, variety and fungicide in low pressure sites, 2, 5, 14, 15, 18 and 21. Error bars show the LSD for the interaction between variety and fungicide.

T2 + 6-8 weeks disease assessment

Of the 8 sites in this group, average septoria severity across all treatments on leaf 2 at this time, ranged from 0.19% at site 16 to 6.91% at site 15.

Table 49: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 2 at T2 + 6-8 weeks in low pressure sites.

Factor	P Value
Site	<.001
Sowing	0.043
Site.Sowing	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001
Site.Sowing.Variety.Fungicide	<.001

As well as site, sowing date, variety and fungicide were also found to be significant factors affecting septoria at this time (Table 49). In this case, unlike the first assessment, the late sowings had slightly higher septoria severities than early sowings (Figure 34) with an average of 3.40% compared to 2.98% on leaf 2. When comparing the different varieties, on average all three groups were significantly different, with the highest disease severity in the susceptible group and the lowest in the moderately resistant (Table 50).

The interaction between variety and fungicide was also significant (Table 49). In the susceptible varieties, the low input programme significantly reduced septoria severity compared to the untreated, the low and medium input programmes were statistically comparable, but the high input programme significantly reduced disease compared to the low. In comparison, there was no significant benefit from applying more than a medium input programme in the moderately susceptible varieties and low input programme for moderately resistant (Table 50). However, the interaction between site, variety and fungicide was also significant (Appendix 19).

Table 50: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the variety and fungicide interaction in low pressure sites, 2, 5, 14, 15, 16, 18, 20 and 21.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	12.66	2.76	1.94	1.20	4.64
Moderately Susceptible	7.45	2.93	1.26	1.48	3.28
Moderately Resistant	3.08	1.43	1.21	0.91	1.66
Average	7.73	2.37	1.47	1.20	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.491	0.567	0.983		

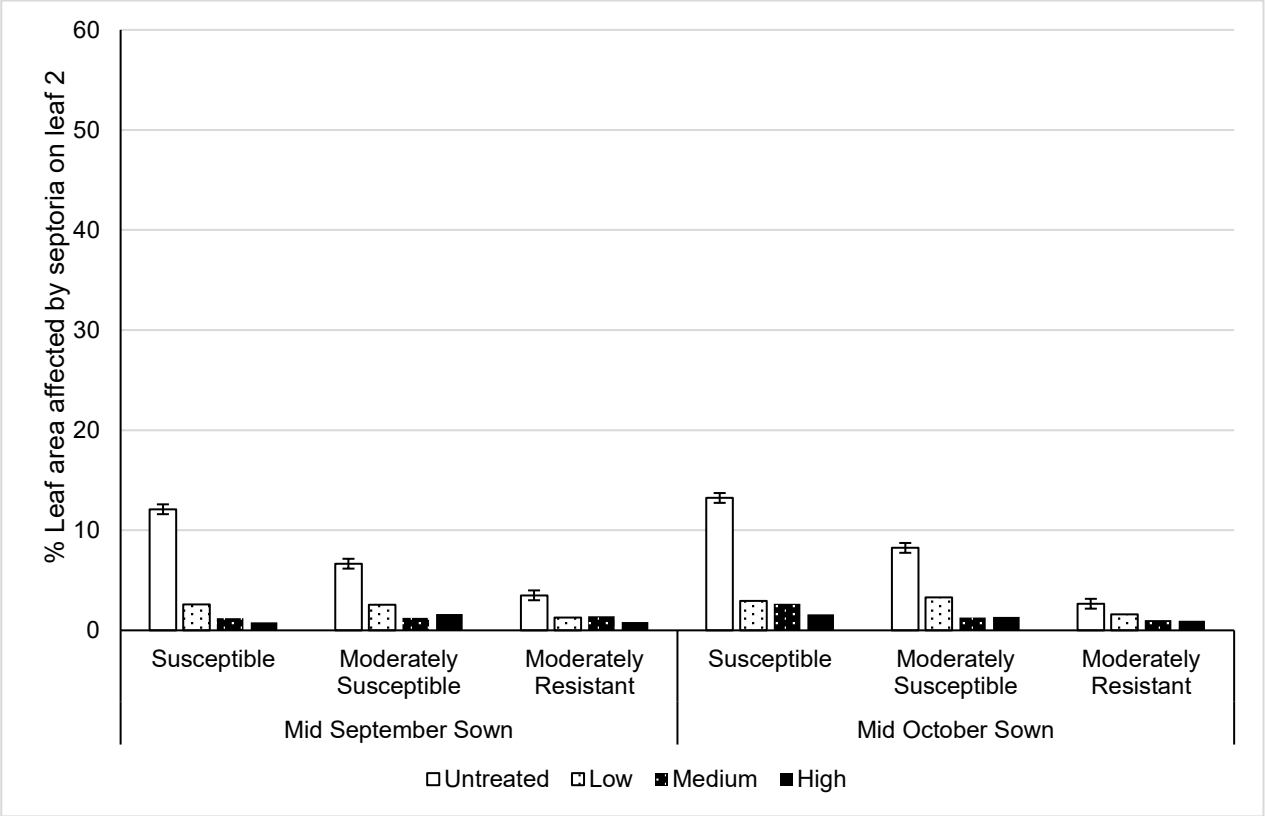

Figure 34: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks, for the interaction of sowing date, variety and fungicide in low pressure sites, 2, 5, 14, 15, 16, 18, 20 and 21. Error bars show the LSD for the interaction between variety and fungicide.

Yield

Yields in this low-pressure group ranged from 5.16t/ha at site 2 to 12.20t/ha at site 18.

Table 51: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for yield in low pressure sites.

Factor	P Value
Site	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Sowing.Fungicide	0.005
Site.Variety.Fungicide	<.001

Site, variety and fungicide were all found to be significant as a single factor (Table 51). On average, the moderately susceptible group achieved the lowest yield, significantly lower than the susceptible and moderately resistant (Table 52).

The interaction between variety and fungicide (Table 51) indicated that for the susceptible and moderately susceptible groups there was a significant benefit on yield from applying up to a medium input programme, whereas for the moderately resistant there was no further benefit from applying more than the low input programme (Table 52). However, the interaction between site, variety and fungicide was also significant suggesting that this response varied by site (Appendix 20).

Table 52: Average yield (t/ha) for the variety and fungicide interaction in low pressure sites, 2, 14, 15, 16, 18, 20 and 21.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	9.39	9.93	10.52	10.46	10.07
Moderately Susceptible	9.25	9.48	10.01	10.01	9.69
Moderately Resistant	9.73	10.31	10.11	10.31	10.12
Average	9.45	9.91	10.21	10.26	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.125	0.144	0.25		

The interaction between sowing date, variety and fungicide was not significant suggesting that this response was consistent across sowing dates (Figure 35).

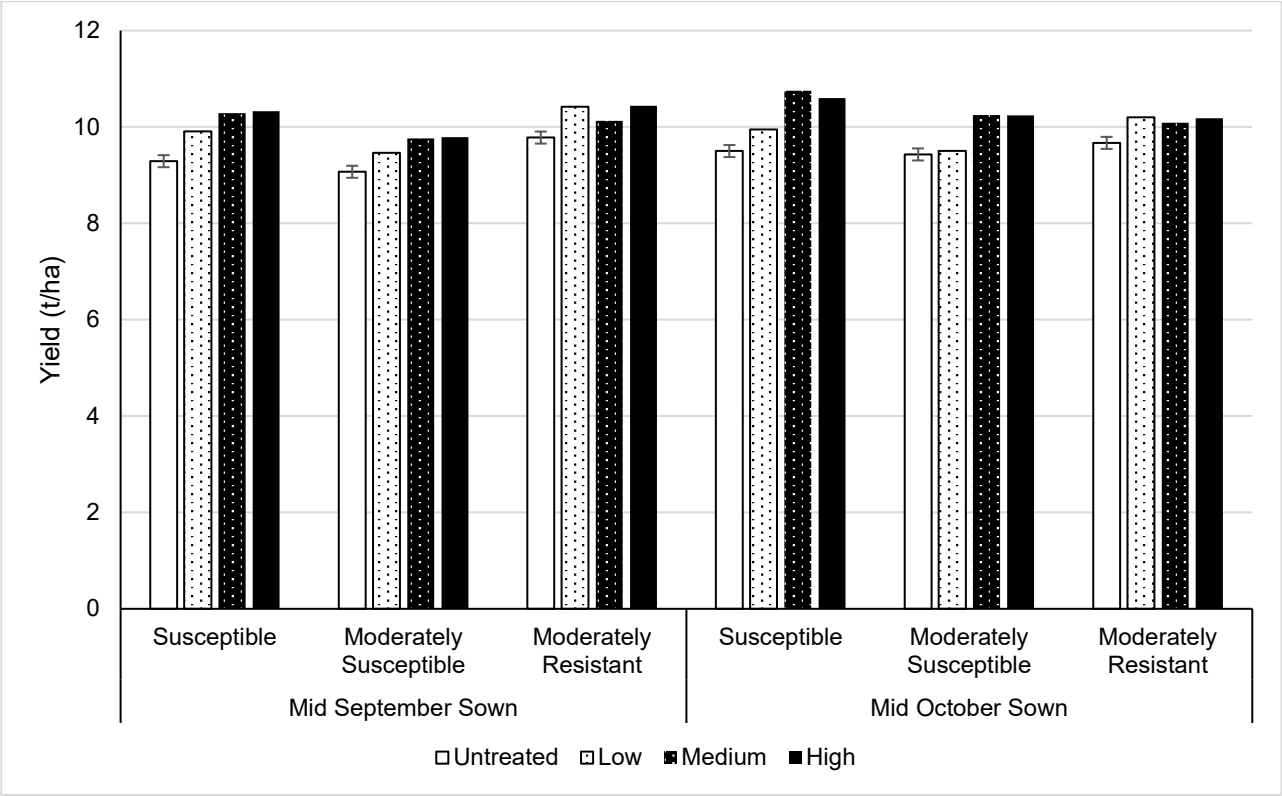

Figure 35: Average yield (t/ha), for the interaction of sowing date, variety and fungicide in low pressure sites, 2, 14, 15, 16, 18, 20 and 21. Error bars show the LSD for the interaction between variety and fungicide.

4.4.2. Medium disease pressure sites

T2 + 2-3 weeks disease assessment

Average septoria severity on leaf 3 in the medium pressure sites ranged from an average of 0.49% at site 25 to 4.90% at site 8.

Table 53: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks in medium pressure sites.

Factor	P Value
Site	0.001
Sowing	<.001
Site.Sowing	0.004
Variety	<.001
Fungicide	<.001
Sowing.Variety	0.003
Site.Fungicide	<.001
Sowing.Fungicide	<.001
Site.Sowing.Fungicide	<.001

As well as site, sowing date, variety and fungicide were all found to be significant factors affecting septoria at this time (Table 53). Early sowings had higher disease severity than later sowings (Figure 36) with an average of 3.63% compared to 0.92% on leaf 3. The susceptible varieties

group had the highest disease severity, significantly higher than the moderately susceptible and moderately resistant groups (Table 54).

In this case the interaction between variety and fungicide was not significant, suggesting that the response to fungicide was consistent across varieties. On average there was no significant benefit from going above a medium input strategy. However, the interaction between site and fungicide was significant, suggesting that this response was not consistent across sites (Appendix 21).

Table 54: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the variety and fungicide interaction in medium pressure sites, 1, 4, 8, 9 and 25.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	7.45	2.01	1.18	1.16	2.95
Moderately Susceptible	5.84	1.57	0.71	0.58	2.17
Moderately Resistant	4.38	1.34	0.70	0.36	1.69
Average	5.89	1.64	0.86	0.70	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	0.123		
LSD	0.651	0.752	1.302		

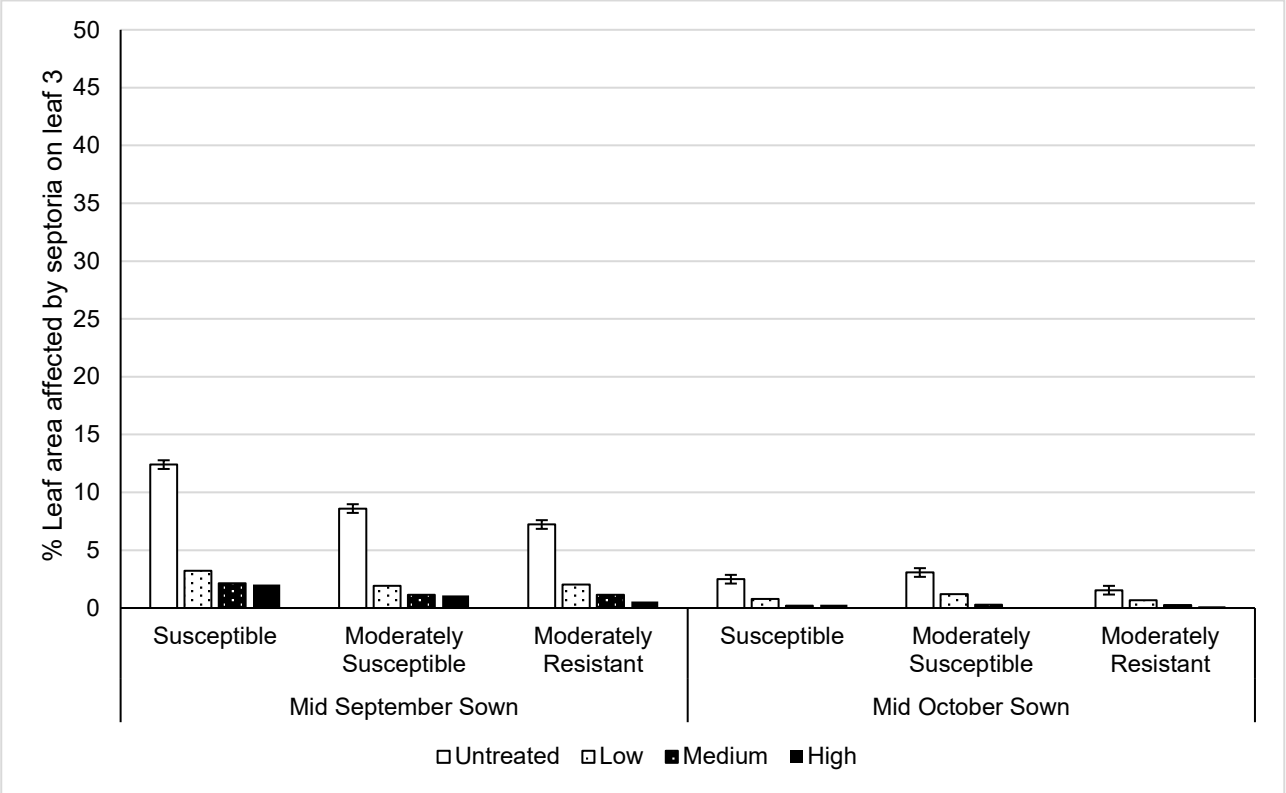

Figure 36: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks, for the interaction of sowing date, variety and fungicide in medium pressure sites 1, 4, 8, 9 and 25. Error bars show the LSD for fungicide.

T2 + 6-8 weeks disease assessment

At T2 + 6-8 weeks, septoria severity within this group varied significantly from 3.22% on leaf 2 on average at site 25 to 7.56% at site 4.

Table 55: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 2 at T2 + 6-8 weeks in medium pressure sites.

Factor	P Value
Site	<.001
Sowing	<.001
Site.Sowing	0.016
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	0.009
Variety.Fungicide	<.001
Site.Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001

Sowing date, variety and fungicide were also found to be significant as single factors (Table 55). On average the early sowing had higher septoria severity than the late sowing (Figure 37) with 6.32% compared to 3.55%. When comparing the different varieties, on average the susceptible group had the highest disease severity, significantly higher than the moderately susceptible and moderately resistant (Table 56).

The interaction between variety and fungicide was also significant (Table 55). For the susceptible group the low input programme significantly reduced septoria severity compared to the untreated, the low and medium input programmes were statistically comparable, but the high input programme significantly reduced septoria compared to the low. Whereas for the moderately susceptible and moderately resistant groups there was no significant benefit from going above a low input programme (Table 56). However, the interaction between site, variety and fungicide was also significant suggesting that the relationship between variety and fungicide was not consistent by site (Appendix 22).

Table 56: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the variety and fungicide interaction in medium pressure sites, 1, 4, 8, 9 and 25.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	18.13	3.65	2.04	1.49	6.33
Moderately Susceptible	13.85	2.45	1.63	1.13	4.76
Moderately Resistant	8.78	3.05	1.37	1.64	3.71
Average	13.59	3.05	1.68	1.42	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	1.078	1.244	2.155		

When comparing variety, sowing date and fungicide effects (Figure 37), late sowings appeared to consistently reduce septoria severity across all varieties and fungicide programmes. As a result, the moderately susceptible variety sown mid-October was comparable to the moderately resistant variety sown mid-September.

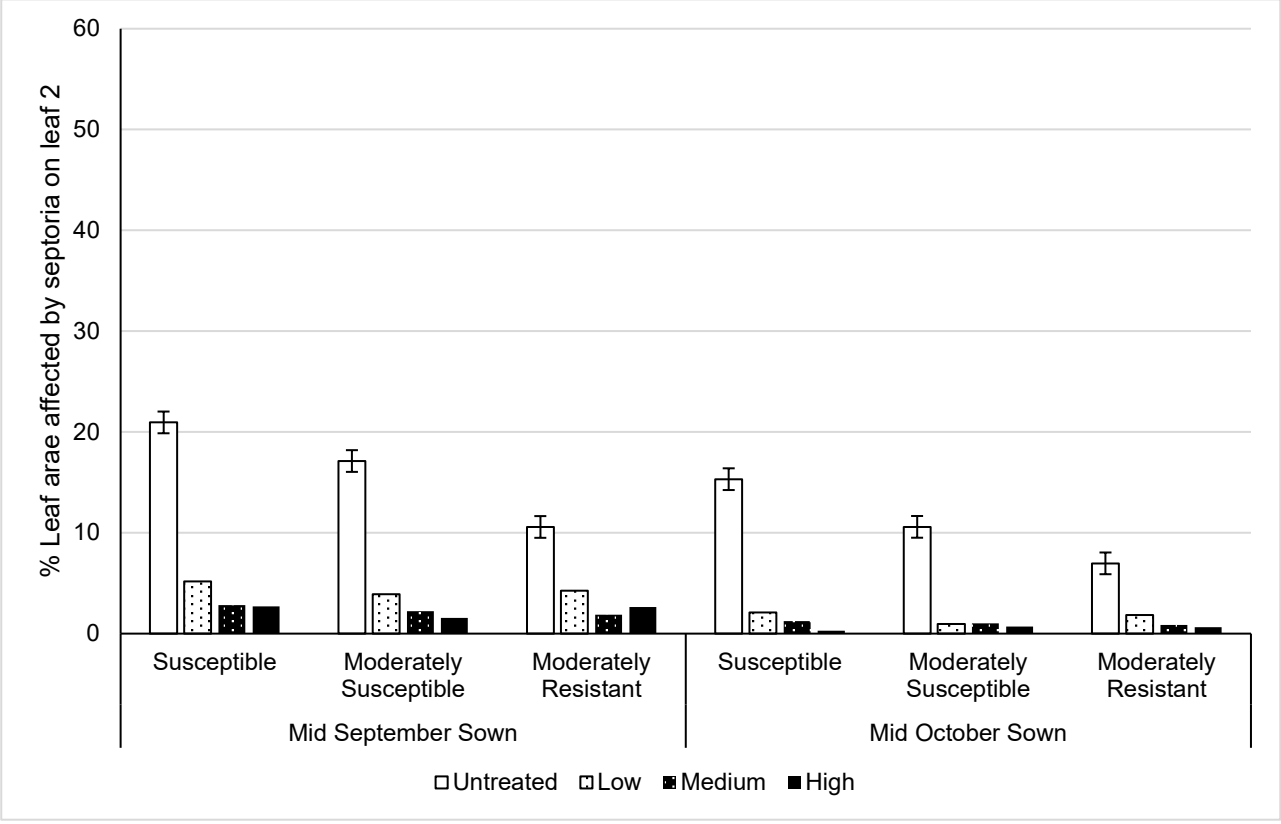

Figure 37: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks, for the interaction of sowing date, variety and fungicide in medium pressure sites, 1, 4, 8, 9 and 25. Error bars show the LSD for the interaction between variety and fungicide.

Yield

Yields in this medium pressure group ranged from 8.36t/ha at site 8 to 10.51t/ha at site 1.

Table 57: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for yield in medium pressure sites.

Factor	P Value
Site	0.002
Site.Sowing	0.041
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	0.032
Variety.Fungicide	0.032
Site.Sowing.Variety	<.001

As well as site, variety and fungicide were also found to be significant as a single factor (Table 57). When comparing the different varieties, the susceptible group achieved the highest yield on average, significantly higher than the moderately susceptible and moderately resistant (Table 58).

There was a significant interaction between variety and fungicide (Table 57). On susceptible varieties, the low and medium programmes were statistically comparable, but the high input programme significantly increased yields compared to the low. For the moderately susceptible varieties, the low and medium input programme were also comparable but the high input programme significantly increased yields above that of the medium. Whereas for the moderately resistant varieties there was no significant benefit from applying above a low input programme (Table 58). In this instance sowing date was not a significant factor affecting yield (Figure 38).

Table 58: Average yield (t/ha) for the variety and fungicide interaction in medium pressure sites, 1, 8, 9 and 25.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	9.07	10.30	10.51	10.77	10.16
Moderately Susceptible	8.99	9.95	9.88	10.31	9.78
Moderately Resistant	9.10	9.77	10.00	9.94	9.70
Average	9.06	10.01	10.13	10.34	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	0.032		
LSD	0.182	0.21	0.364		

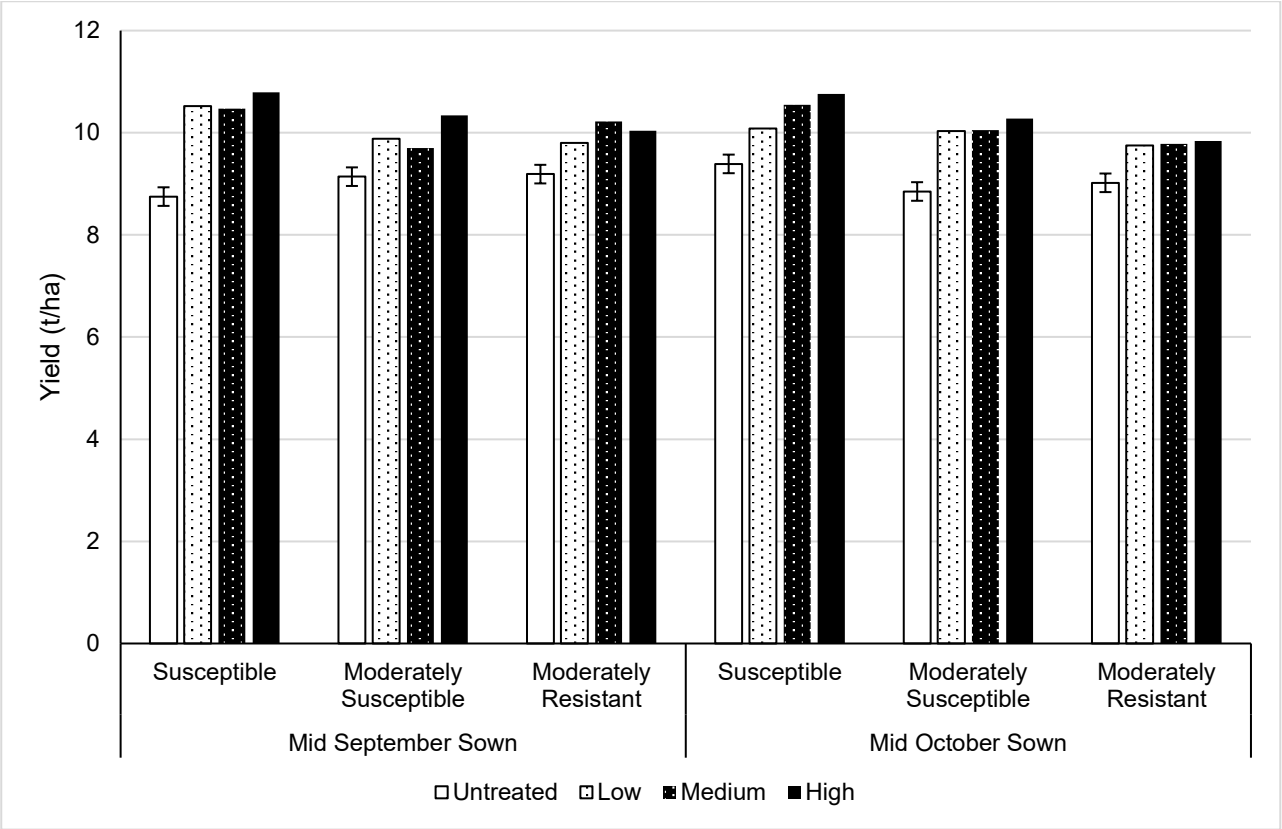

Figure 38: Average yield (t/ha), for the interaction of sowing date, variety and fungicide in medium pressure sites, 1, 8, 9 and 25. Error bars show the LSD for the interaction between variety and fungicide.

4.4.3. High disease pressure

T2 + 2-3 weeks disease assessment

Average septoria severity in the high-pressure group ranged from 4.08% at site 24, to 19.39% at site 13.

Table 59: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks in high pressure sites.

Factor	P Value
Site	<.001
Sowing	<.001
Site.Sowing	<.001
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Sowing.Variety	<.001
Site.Fungicide	<.001
Sowing.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Sowing.Fungicide	<.001
Site.Variety.Fungicide	<.001
Site.Sowing.Variety.Fungicide	<.001

Site, sowing date, variety and fungicide were all found to be significant as single factors (Table 59). On average, early sowing had higher disease severity than late sowing with 10.87% compared to 4.79%. When comparing the different varieties, under high disease pressure, each group was found to be significantly different, with the highest disease severity in the susceptible group and the lowest in the moderately resistant (Table 60).

There was a significant interaction between variety and fungicide (Table 59). In both the susceptible and moderately susceptible groups, the low input programme significantly reduced septoria severity compared to the untreated, the low and medium inputs were comparable, but the high input programme significantly reduced septoria compared to the medium. Whereas in the moderately resistant varieties there was no significant benefit from going above a low input programme (Table 60). However, the interaction between site, variety and fungicide was also significant suggesting that this relationship varied by site (Appendix 23).

Table 60: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the variety and fungicide interaction in high pressure sites, 3, 6, 12, 13, 19 and 24.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	31.14	9.71	9.67	4.95	13.87
Moderately Susceptible	14.47	4.31	4.88	2.29	6.49
Moderately Resistant	7.59	1.64	2.32	1.05	3.15
Average	17.73	5.22	5.62	2.77	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	1.073	1.238	2.145		

The interaction between sowing date, variety and fungicide was not significant in this case. However, it is clear that sowing in mid-October reduced septoria severity in the untreated of each variety compared to when sown mid-September. As a result, a susceptible variety sown mid-October was comparable to a moderately susceptible variety sown mid-September (Figure 39).

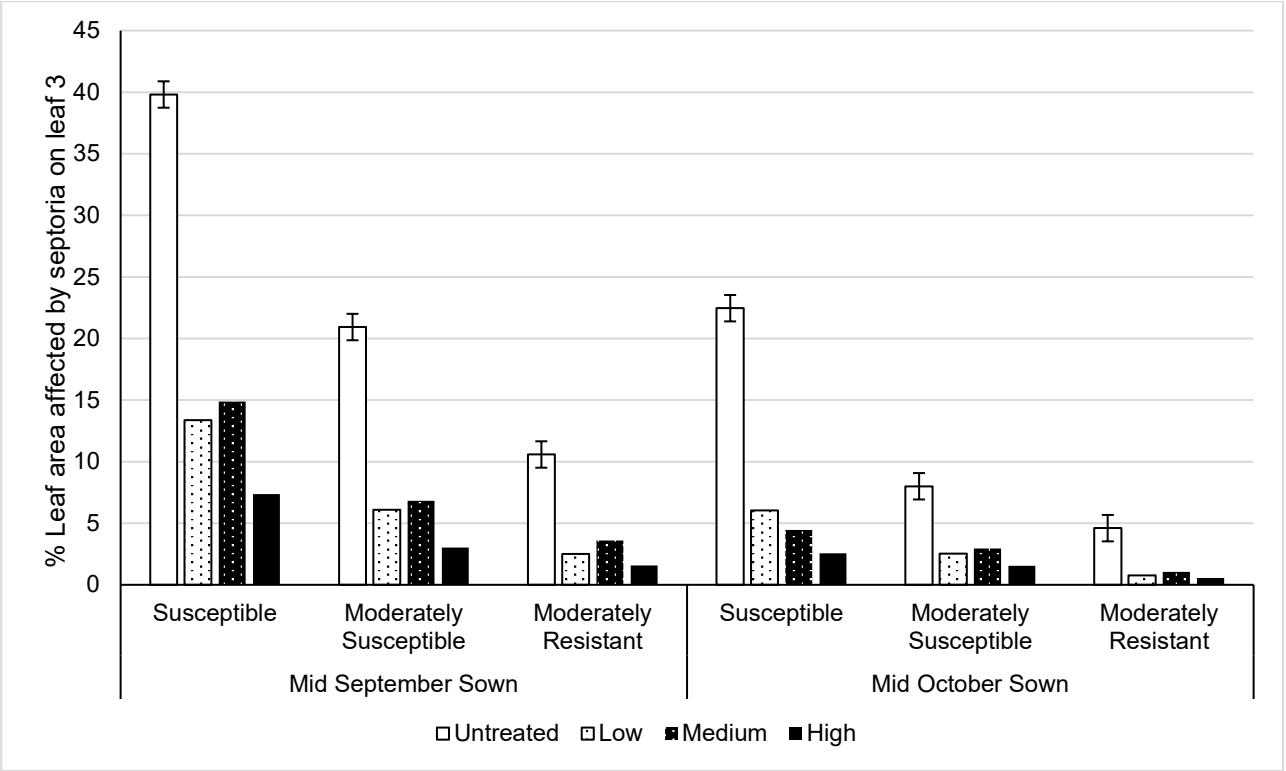

Figure 39: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks, for the interaction of sowing date, variety and fungicide in high pressure sites, 3, 6, 12, 13, 19 and 24. Error bars show the LSD for the interaction between variety and fungicide.

T2 + 6-8 weeks disease assessment

Average septoria severity at this time on leaf 2 varied significantly from 12.74% on average at site 12, to 30.07% at site 22.

Table 61: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 2 at T2 + 6-8 weeks in high pressures sites.

Factor	P Value
Site	<.001
Sowing	<.001
Site.Sowing	0.002
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	0.003
Site.Sowing.Fungicide	0.009
Site.Variety.Fungicide	<.001
Sowing.Variety.Fungicide	0.001

Sowing, variety and fungicide were also found to be significant factors affecting septoria severity at this time (Table 61). On average, early sowing had higher disease severity than late sowing with

an average of 23.43% compared to 18.48%. When comparing the different varieties, as seen at the previous assessment, all three variety groups were significantly different. The susceptible group had the highest severity and the moderately resistant the lowest.

The interactions between variety and fungicide, and between variety, fungicide and sowing date were found to be significant, suggesting that the relationship between variety and fungicide was affected by sowing date in this high-pressure group (Table 61). The level of disease in the untreated was similar across all the variety, sowing date combinations, with the exception of the moderately resistant variety sown mid-October, which was significantly lower. When sown mid-September, in the susceptible and moderately susceptible groups, septoria severity decreased with each increase in fungicide input from untreated to high. However, due to a high LSD value, the difference between the medium and high input programmes wasn't quite significant in the susceptible varieties. In the moderately resistant varieties, there was no significant benefit from applying more than a medium input strategy. When sown mid-October, there was a significant benefit of applying up to a high input programme in the susceptible varieties, medium input programme in the moderately susceptible varieties, and low input programme in the moderately resistant (Figure 40).

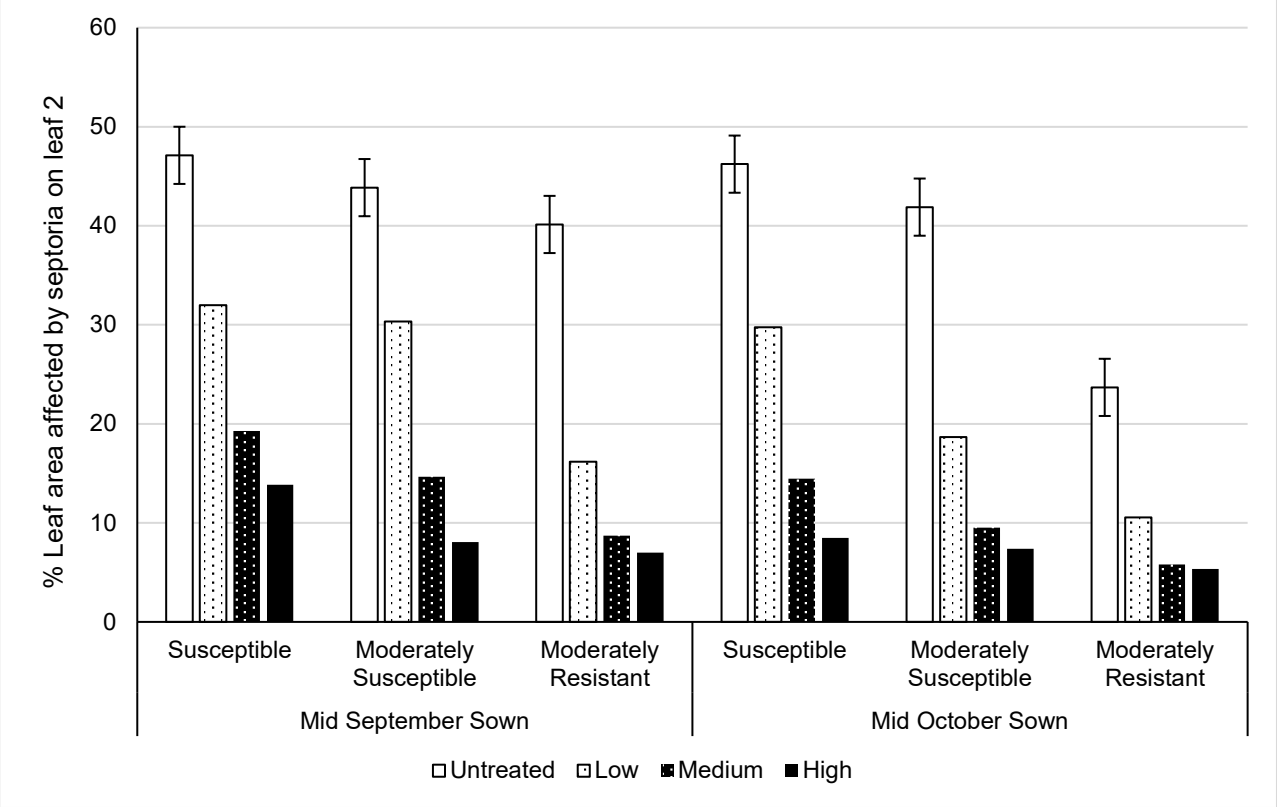

Figure 40: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks, for the interaction of sowing date, variety and fungicide in high pressure sites, 3, 6, 11, 12, 19, 22 and 24. Error bars show the LSD for the interaction between sowing date, variety and fungicide.

Yield

Of the 8 sites included in this high-pressure group, site 3 had the lowest yield with 9.89t/ha and site 12 the highest with 11.76t/ha.

Table 62: Factors and interactions found to be statistically significant (P<0.05) by analysis of variance for yield in high pressure sites.

Factor	P Value
Site	<.001
Sowing	0.004
Site.Sowing	0.008
Variety	<.001
Fungicide	<.001
Site.Variety	<.001
Site.Fungicide	<.001
Variety.Fungicide	<.001
Site.Sowing.Variety	<.001
Site.Variety.Fungicide	<.001

Site, sowing date, variety and fungicide were all found to be significant factors affecting yield (Table 62). On average, later sowing produced higher yields (Figure 41) with an average of 10.77t/ha, compared to 10.41t/ha when sown early. When comparing the different varieties, all three were significantly different with the highest yield achieved by the moderately resistant group and the lowest the susceptible (Table 63).

The interaction between variety and fungicide was also significant (Table 62). For the susceptible group, yield increased with each increase in fungicide input from untreated to high, however the difference between the medium and high input programmes wasn't quite statistically significant. In the moderately susceptible group, the low and medium input programmes were statistically comparable but the high input programme significantly increased yield compared to the low. Whereas in the moderately resistant variety there was no significant benefit from applying more than a low input programme (Table 63). However, the interaction between site, variety and fungicide was also significant, suggesting that this relationship varied by site (Appendix 24).

Table 63: Average yield (t/ha) for the variety and fungicide interaction in high pressures sites, 3, 6, 11, 12, 13, 19, 22 and 24.

	Fungicide				
Variety	**Untreated**	**Low**	**Medium**	**High**	**Average**
Susceptible	8.82	10.19	10.86	11.10	10.24
Moderately Susceptible	9.51	10.84	11.06	11.26	10.67
Moderately Resistant	10.06	11.03	11.16	11.22	10.87
Average	9.46	10.69	11.03	11.19	
	Variety	**Fungicide**	**Var.Fung.**		
P Value	<.001	<.001	<.001		
LSD	0.119	0.138	0.238		

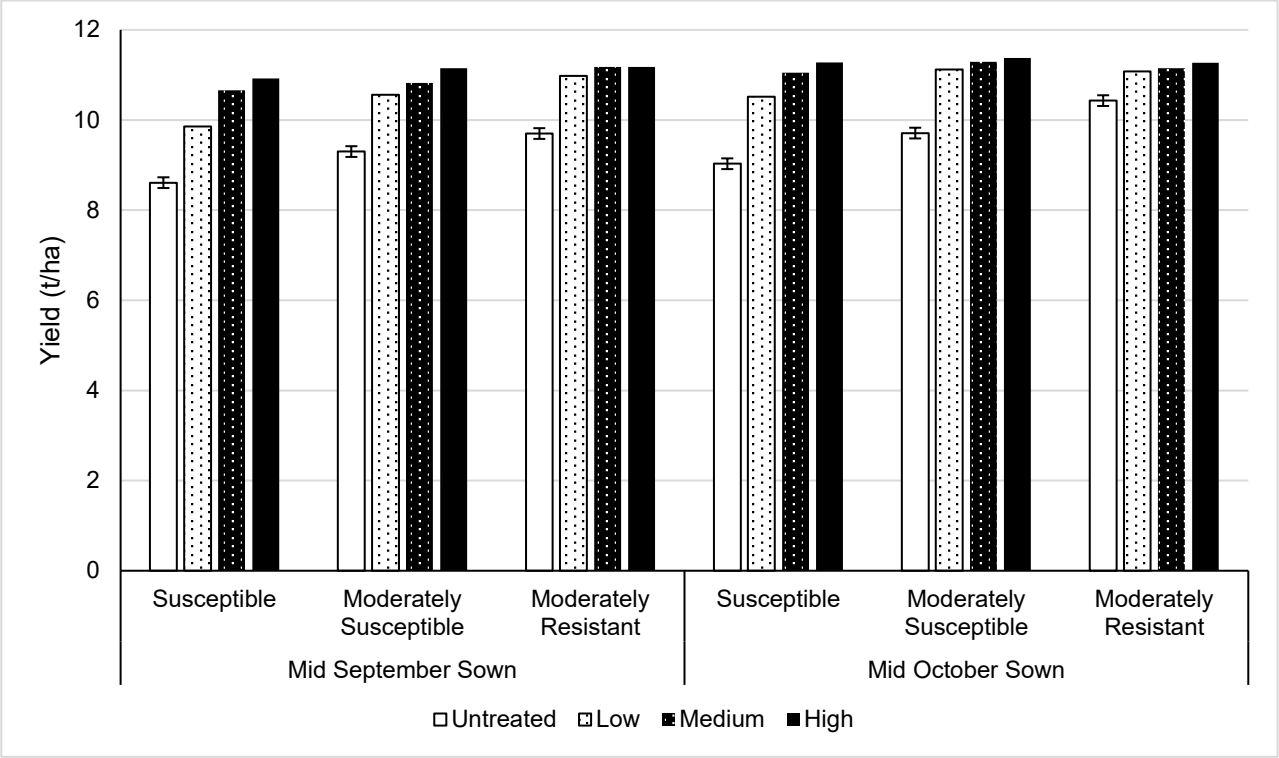

Figure 41: Average yield (t/ha), for the interaction of sowing date, variety and fungicide in high pressure sites, 3, 6, 11, 12, 13, 19, 22 and 24. Error bars show the LSD for the interaction between variety and fungicide.

4.5. Impact of seed rate

Seed rate was included as a factor in trials completed between 2016 and 2018. All trials within this period were analysed together to summarise the effect of seed rate on septoria.

Table 64: Factors and interactions containing seed rate, found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 3 at T2 + 2-3 weeks across sites from 2016 to 2018.

Factor	P Value
Seed Rate	0.036
Site.Seed Rate	<.001
Site.Sowing.Seed Rate	0.018
Site.Seed Rate.Variety	0.015
Site.Seed Rate.Fungicide	<.001
Site.Sowing.Seed Rate.Fungicide	0.009
Sowing.Seed Rate.Variety.Fungicide	0.032

At T2 + 2-3 weeks, seed rate was found to be significant as a single factor (Table 64). On average the high seed rate had greater septoria severity than the lower seed rate with 5.30% compared to 4.95%. However, the interaction between site and seed rate was also significant suggesting that this response varied by site (Appendix 25).

Table 65: Factors and interactions containing seed rate, found to be statistically significant (P<0.05) by analysis of variance for septoria severity on leaf 2 at T2 + 6-8 weeks across sites from 2016 to 2018.

Factor	P Value
Site.Seed Rate.Fungicide	0.011
Site.Sowing.Seed Rate.Variety	<.001

By T2 + 6-8 weeks there were no significant differences between seed rates with an average septoria severity of 8.32% for the high, compared to 8.27% for the low. Furthermore, there were very few significant interactions with seed rate at this time (Table 65).

Table 66: Factors and interactions containing seed rate, found to be statistically significant (P<0.05) by analysis of variance for yield across sites from 2016 to 2018.

Factor	P Value
Seed Rate	<.001
Site.Seed Rate	<.001
Sowing.Seed Rate	<.001
Site.Sowing.Seed Rate	<.001
Site.Seed Rate.Variety	0.011
Site.Seed Rate.Fungicide	0.008
Site.Sowing.Seed Rate.Fungicide	<.001
Site.Seed Rate.Variety.Fungicide	0.003
Sowing.Seed Rate.Variety.Fungicide	0.007

Seed rate was found to be a significant factor affecting yield, with an average of 10.01t/ha for the high seed rate and 9.65t/ha for the low (Table 66). However, once again the interaction between site and seed rate was significant suggesting that this relationship was not consistent across all sites (Appendix 26). This could suggest that the plant population in the low seed rate treatments was sub optimal for yield. The interaction between sowing date and seed rate was also found to be

significant. This is not surprising as both factors can influence yield in the absence of disease. On average, both sowing dates in the high seed rate, and the low seed rate sown late were statistically comparable. All had significantly higher yields than the low seed rate sown early (Table 67). The low seed rate in the late sowing and the high seed rate in the early sowing were both targeting 160 plants/m^2, whereas the early sown low seed rate was targeting 80 plants/m^2. Therefore, this data suggests that the low seed rate used in this project for the early sowing was sub-optimal for yield. However, the interaction between site, sowing date and seed rate was also significant suggesting that this response was not consistent across sites (Appendix 27).

Table 67: Average yield (t/ha) for the interaction between sowing date and seed rate across all sites from 2016 to 2018, , excluding 4, 5 and 17.

Sowing	High Seed Rate	Low Seed Rate
Early	9.94	9.43
Late	10.08	9.88
P value	<.001	
LSD	0.226	

4.6. How does sowing date affect resistance ratings?

Within this data, there was no correlation between the difference between average early sown and late sown logit severity values and variety resistance ratings. There were also no significant differences between the slope or intercepts of the fitted regression lines of early and late sown logit severity values for the three different resistance groups. Therefore, a common regression line was fitted to all of the data (Figure 42). The regression line shows that severity was lower on average in late sown crops than early sown crops, when comparing crops sown at the same site in the same year.

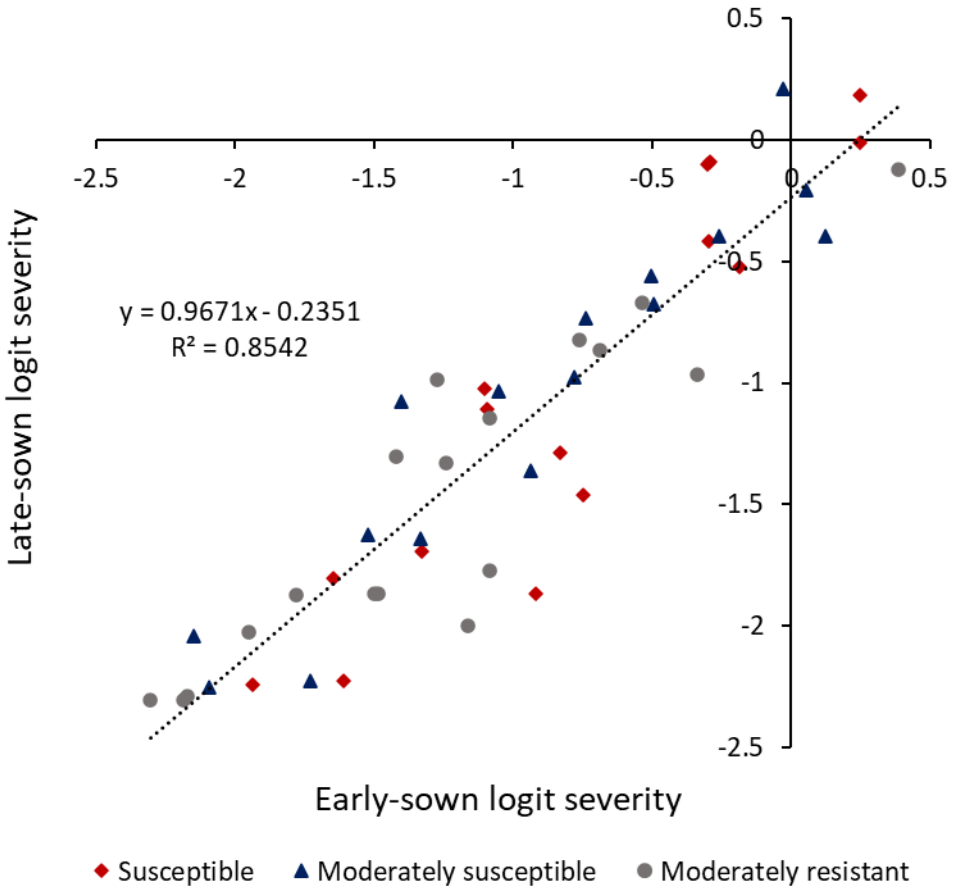

Figure 42: Regression line between average early-sown logit severity and late-sown logit severity.

The predicted effective septoria resistance ratings for early (average of 22nd September) and late (average of 20th October) sown crops corresponding to each value of the Recommended List resistance ratings (based on an average sowing date of 7th October) are shown in Figure 43. Compared to the Recommended List ratings, on average early sowing decreased the effective rating by approximately 0.6, whereas late sowing increased the effective rating by approximately 0.6, for the range of varietal resistance ratings tested in this project.

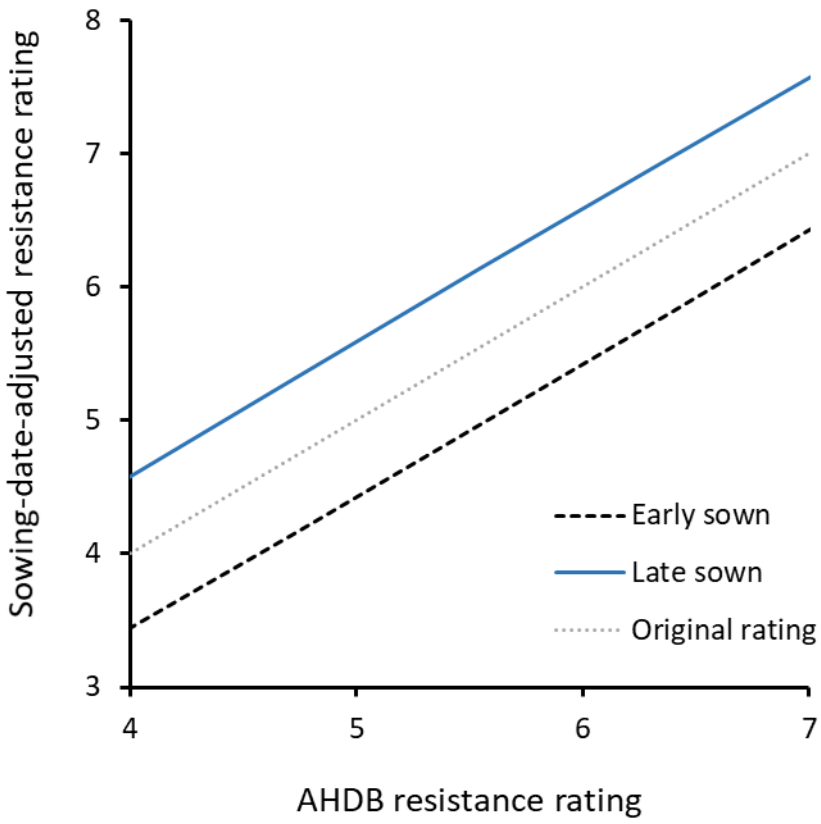

Figure 43: Adjusted septoria resistance ratings for early- and late-sown crops.

5. Discussion

5.1. Site

Within this report, data have been presented and summarised as an average across several sites. However, site was found to be a significant factor throughout, both on its own and in interaction with other factors, suggesting that the response at some sites differed from the average. This is to be expected as each site will be influenced by different weather conditions, soil types, water retaining capacities and yield potentials. Therefore, highlighting the importance of managing each field on an individual basis.

5.2. Variety

Variety consistently had a significant effect on septoria severity at both disease assessments. In all seasons and disease pressure groups, the average level of disease in each variety reflected the resistance ratings, with the highest disease severity in the susceptible group and the lowest in the moderately resistant. When all sites were analysed together, there was a significant difference in the average septoria severity between all three variety groups, both when assessed at T2 + 2-3 weeks and T2 + 6-8 weeks (Figure 27, Figure 28).

Variety was also found to significantly affect yield in all seasons and disease pressure groups. The highest yielding group in each season was driven by both disease and inherent differences in the yield potential of each variety. As disease pressure varied by season, and the varieties used changed over the course of the project, the highest yielding group differed. When averaged across all sowing dates and fungicide programmes, in 2016 (Table 10), 2019 (Table 30) and 2020 (Table 37), the moderately resistant variety group achieved the highest yields, whereas in 2017 (Table 17) and 2018 (Table 24), the susceptible group achieved the highest yields. This was because in 2016, 2019 and 2020, across the fungicide programmes yields were generally lower for the susceptible group than the moderately resistant. In 2017 and 2018 the susceptible group had the highest treated yields, resulting in a higher yield than moderately resistant varieties on average. The susceptible and moderately resistant varieties in trials between 2016 to 2018 were pre-dominantly represented by Santiago and Revelation. Santiago had higher treated yields in 2017 and 2018 because Santiago was a higher yielding variety, with a difference of 5% compared to Revelation in 2017 RL trials and 4% in 2018 (AHDB, 2020b). The results in 2016 were influenced by high disease pressure in Ireland resulting in lower yields for the susceptible variety, Cordiale, and therefore a lower yield on average than the moderately resistant varieties.

The effect of variety on septoria severity has been widely reported. Gladders et al. 2001, found that the use of more resistant varieties reduced the severity of septoria*,* with very few crops exceeding the 5% severity threshold, where varieties with a resistance rating of 7 were grown. Analysis of the weather factors that influence septoria showed that all varieties were influenced by similar weather factors, however, rainfall appeared to be more important for resistant varieties, than those that were intermediate. Therefore, suggesting that more rain is required in resistant varieties to generate a damaging epidemic (te Beest et al. 2009). This will in part be due to resistance genes which affect the development of the pathogen within the plant (Brown et al. 2015). But may also be due to differences in the canopy architecture enabling disease escape (Lovell et al. 2004).

In this project, the use of susceptible varieties resulted in greater yield loss than resistant varieties, a finding supported by Said et al. (2016) and observed in the AHDB Recommended List (AHDB 2021). When all sites were analysed together, the susceptible group had the lowest yield when left untreated, followed by the moderately susceptible, and the moderately resistant achieved the highest yield when averaged across sowing date. As a result, the response to the high input fungicide programme was highest in the susceptible varieties with an average increase of 1.71t/ha, and lowest in the moderately resistant with an increase of 0.90t/ha (Figure 30).

Variety is undoubtably an important factor for the control of septoria. The use of more resistant varieties reduces the risk of a damaging epidemic and substantial yield loss. As such, variety choice should be utilised as a risk management strategy.

5.3. Fungicides and interactions with Variety

As with variety, fungicide was consistently found to have a significant effect on disease control and yield. The use of fungicides significantly reduced disease levels and increased yields in all seasons and disease pressure groups, showing the value of fungicides for control of septoria. However, the differences between the different fungicide programmes varied by variety, season and disease pressure. For the susceptible varieties, there was a significant benefit in yield from applying up to a medium input strategy in 2017 (Table 17), 2018 (Table 24) and 2019 (Table 30) and a high input strategy in 2016 (Table 10) and 2020 (Table 37). For the moderately susceptible varieties there was a significant benefit in yield from applying up to a low input strategy in 2017, medium input strategy in 2016 and 2018 and a high input strategy in 2019 and 2020. Whereas for the moderately resistant group there was a significant benefit in yield from applying up to a low input strategy in 2017, 2018 and 2019, medium in 2016 and high in 2020. It was noted that in 2020, there was a bigger difference between the medium and high input strategies, which could be due in part to the inclusion of new chemistry, Revystar XE (fluxapyroxad and mefentrifluconazole), in the high input programme. Furthermore, the moderately resistant variety in 2020 was Firefly (rated 7 out of 9 on th AHDB recommended list). This variety performed poorly overall in these trials and in the AHDB RL in 2020 conditions, with a reduction of 6% in the untreated yield compared to the 5 year mean in RL trials (AHDB, 2020b). It is thought this may have been due to climatic conditions that didn't suit this variety, or the possible presence of yellow or brown rust. Both were reported in some crops of Firefly in 2020. Although not recorded here it is possible that yellow rust early in the spring, or brown rust at the end of the season, may have negatively affected Firefly in these trials. This would explain the requirement for a high input programme in moderately resistant varieties for this season alone. On average, across all sites and seasons, there was a yield benefit from applying up to a high input programme in the susceptible and moderately susceptible varieties, and low input programme in the moderately resistant (Table 43). The effect of fungicide on specific weight tended to be smaller than the effect on yield with a reduction in specific weight where septoria was not adequately controlled (Table 19). This suggests that for susceptible varieties a medium to high input programme is often required, whereas in more resistant varieties (rated 6 and above) a low to medium input strategy is usually more appropriate.

When yield is converted to output, it is clear that the increase in output from fungicides is much less in more resistant varieties (Table 45). As such it may be easy to overspend when accounting for the cost of fungicide applications, which could reduce margins. A similar study that looked at optimum fungicide dose for margin, in moderate to high pressure situations in Ireland, found that

two applications at half rate of either azole only or azole + SDHI, resulted in a higher margin in varieties with a resistance rating of 8 than where the full rate was applied in varieties rated 5 and 7 (Lynch et al. 2017). It has also been shown that there is potential for the cost of control of diseases to be almost halved if resistant varieties are chosen (Jørgensen et al. 2014). This suggests that tailoring of fungicide inputs to the variety can be of economic benefit.

Fungicides have been relied on for control of septoria. However, this had led to resistance development in all single-site modes of action. Since 1970, when systemic fungicides were introduced, the incidence of resistance has increased, and the time taken for resistance to emerge has decreased. In some cases, resistance has been detected within two years of a product being brought to the market (Brent and Hollomon, 2007). At the time of writing, the two most effective and widely used modes of action against septoria, azoles and SHDIs, are decreasing in efficacy. Studies investigating the efficacy of epoxiconazole and prothioconazole, concluded that the effect of these actives on septoria has become more variable, and efficacy has declined over the last decade (Blake et al. 2018, Jørgensen et al. 2020). Furthermore, isolates that result in a moderate loss of sensitivity to SDHIs (C-W80S, C-N86S and C-T79N) have been detected in the UK, as has C-H152R isolate which has a stronger impact on SDHI sensitivity (Rehfus et al. 2018). Therefore, the effective life of existing and new chemistry must be protected through the use of resistance management strategies. The Fungicide Resistance Action Group UK (FRAG-UK, 2021) guidance supports the use of reduced rates and mixtures in reducing selection pressure for resistance and stewarding products based on field and modelling data (Hobbelen et al. 2014).

Furthermore, the move to more stringent registration criteria, which includes consideration on the risks products pose to human health, has resulted in the withdrawal of a number of active ingredients including chlorothalonil and epoxiconazole (Hillocks 2012). Therefore, as the number of available actives decreases, and those that are available are at risk of resistance development, even with the addition of new chemistry, it is vital that growers adopt an Integrated Pest Management (IPM) approach to disease control. Reducing reliance on pesticides through the use of cultural control measures (variety and sowing date).

5.4. Sowing date

Sowing date was frequently observed as a significant factor affecting septoria severity in this project. This effect was clearest at the first disease assessment, where in each season, early sowing consistently increased septoria severity, compared to late sowing. The impact of sowing date could still be found at the second disease assessment, on average early sowing had higher septoria severity than late sowing in 3 of the 5 seasons (2017, 2019 and 2020). In 2016 and 2018, the differences were negligible (Figure 8, Figure 16). Furthermore, when the sites were analysed by disease pressure, the differences between early and late sowings appeared to be greater under

higher disease pressure situations. At the first assessment, disease severity increased incrementally in the early sown, compared to the late, for the low, medium and high disease pressure site groups respectively (Figure 33, Figure 36, Figure 39). At the second assessment, disease pressure was marginally higher in the late sowings for the low disease pressure group (Figure 34), whereas in the medium and high disease pressure groups disease severity was significantly higher in the early sowings (Figure 37, Figure 40).

Sowing date was found to significantly affect yield in 2016, 2019 and in the high disease pressure group. In all three cases, later sowings had higher yields than the early (Figure 9, Figure 21, Figure 41). Sowing date was only found to significantly affect specific weight in 2016, where on average, the late sowings had higher specific weight than the early (Figure 10). However, this response in yield and specific weight could be, in part, due to conditions being more favourable during grain filling for the later sown crops.

These results are supported by the survey of diseases in treated winter wheat crops in England and Wales from 1976 to 1988, which found higher disease levels in the earlier sown crops in 1979, 1987 and 1988. However, in 1981 and 1985 the disease was more severe in later sown crops (Polley et. al. 1991). When summarising the survey data from 1985 to 1996, it was reported that there was a substantial reduction in the number of crops which exceeded the 5% severity threshold when delaying sowing. Crops sown in November rarely exceeded the threshold, and the risk of disease was reduced by sowing in October rather than September (Gladders et al. 2001). This is because seedlings from crops sown in early autumn will emerge earlier than later sown crops, while temperatures are higher, and therefore more conducive to the establishment of septoria (Fones et al. 2015, Meynard et al. 2003). As a result, the start of the epidemic is earlier in early sown crops, resulting in higher levels of disease.

In this project, early sowing (average date of 22nd September) was predicted to decrease the effective varietal septoria resistance rating by 0.6 compared to the average represented by the Recommended List ratings (average sowing date of 7th October), whereas late sowing (average date 20th October) was predicted to increase the effective resistance rating by 0.6, for the range of varietal resistance ratings tested in this project (Figure 43). Therefore, suggesting that delaying drilling by 4 weeks from the 22nd September to 20th October reduced the resistance rating of a variety by approximately 1.2. This analysis provides an estimate of the effect of early or late sowing on septoria disease risk on a scale that is familiar to growers and can be used to support variety selection and management decisions.

This work indicates that sowing date is an important factor that should be considered in control of septoria. Whilst chemistry is available for the control of this disease, this may be unlikely to govern

growers' decisions, as later sowings are at increased risk of adverse weather conditions, creating inappropriate sowing conditions that can prevent winter sown crops from being planted at all. However, many factors govern sowing date, winter wheat crops are sown from late August to early March in some instances, the knowledge that later sowings may require less fungicide than early sowings should allow growers to adjust their programmes to good effect. Additionally, when sowing several varieties of different resistance ratings, it would be advantageous to drill the most resistant varieties first, and leave the most susceptible to last, where all other agronomic factors are equal.

5.5. Seed rate

Higher seed rates were associated with higher levels of disease at some sites and in some seasons (particularly 2018) however the effects tended to be small and often inconsistent. At the first assessment (T2 + 2-3 weeks), seed rate was only found to be a significant factor in 2018 (Table 20). Here the higher seed rate appeared to slightly increase septoria severity compared to the low, with 9.04% compared to 7.84% respectively. Therefore, when all sites were analysed together from 2016 to 2018, seed rate was found to be significant (Table 64). At the second assessment (T2 + 6-8 weeks), seed rate was also only a significant factor in 2018, with higher septoria severity, where higher seed rates were used (Table 22). However, the difference between seed rates were even smaller with 3.15% in the low compared to 3.92% in the high, and therefore when all sites were analysed together, seed rate was not found to be significant. It is possible that the effect of seed rate was more visible in 2018 due to high rainfall during March and April, promoting the development of septoria early in the season, before tiller death. At this stage, the difference in the number of shoots/m^2 between the different seed rates may have been more influential. Tillers die between stem extension and flowering with higher losses in crops with more shoots, therefore reducing the difference in shoots/m^2 between high and low seed rates.

Seed rate was found to significantly increase yields in all three seasons where seed rate was investigated (2016, 2017 and 2018) (Table 9, Table 16, Table 23) and was also significant when all sites were analysed together (Table 66). Drilling at lower seed rates can increase the risk of poor crop establishment, particularly in wet seasons or locations with high slug counts where establishment is reduced. It is considered the low seed rates used in this project in some cases may have resulted in sub-optimal plant populations for yield. For specific weight, seed rate was only significant in 2016 (Table 11), where the higher seed rate resulted in higher specific weight. These effects on yield and specific weight are not surprising, as seed rate can influence yield and grain quality in the absence of disease.

Changing the seed rate of a crop can alter the crop canopy microclimate. High seed rates have been shown to reduce temperature and increase relative humidity, resulting in increased septoria severity (Tompkins et. al. 1993). Other work has shown that disease increased progressively with

each increase in tiller density. However, significant differences in disease were only observed at tiller densities well below optimal for crop yield (Ansar et. al. 2010). Crop density may have positive and negative effects on the progress of the septoria epidemic. A more conducive canopy microclimate may be partly countered by less splash dispersal and poorer movement of inoculum in a denser canopy (Eyal 1981). Although increasing seed rate may increase septoria severity, it is considered that this effect is small and inconsistent and as such, it is thought to be the least important of the factors tested.

6. Conclusion

This project has shown that seed rate, sowing date, variety and fungicide can all affect septoria severity in crops of winter wheat. In some cases, increased seed rates resulted in higher septoria severity values by generating a more conducive microclimate for disease. However, this effect was often small and inconsistent, and as such seed rate is thought to be the least important of the factors tested. Sowing in mid-September often resulted in higher disease pressure than sowing in mid-October, as early sown crops were exposed to septoria spores earlier in the season when conditions are more favourable for disease establishment. Sowing date was found to be an important factor that should be considered when establishing a crop and deciding on fungicide inputs. For example, when sowing several varieties of different resistance ratings, the most resistant varieties should be drilled first, and the most susceptible left to last, where all other agronomic factors are equal. However, the most influential factors were variety and fungicide which cannot be discussed in isolation, as the effect of fungicides varied by variety. The severity of septoria was lower in varieties with greater resistance to this pathogen, and therefore the yield response and increase in output from fungicides was also lower than in susceptible varieties, presenting growers the opportunity to reduce their fungicide inputs in order to maximise margins.

As restrictions on fungicide use and development of resistance reduce the number of actives available for use on septoria, growers should utilise all available tools using an IPM approach. Management strategies for the control of this pathogen should start before the crop is drilled by careful selection of variety, using the AHDB RL, and consideration of sowing date. Fungicide use should be the last line of defence and should take into account both the variety and sowing date. This project targeted Septoria at T1 and T2, with an overspray at T3. Rust risk was reduced with a strobilurin spray at T0. The level of input targeting septoria was altered by changing the products and rates used. However, the same can be achieved by reducing the number of applications. With the development of more resistant varieties, it raises the question whether a two spray programme or even a single fungicide application is more appropriate in some instances. Future work would benefit from investigating the value of spray timings in resistant varieties to provide growers the confidence to reduce inputs in this way.

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8. Appendix

*Appendix 1: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the interaction between site, variety and fungicide in 2016. *Data which did not have a reliable score due to a lack of green leaf area.*

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
1	**Susceptible**	8.41	1.77	1.88	0.73
	Moderately Susceptible	4.47	1.21	0.71	0.65
	Moderately Resistant	6.12	1.52	1.35	0.73
2	**Susceptible**	*	1.66	0.44	0.95
	Moderately Susceptible	5.72	5.11	1.39	1.59
	Moderately Resistant	1.17	0.33	0.25	0.59
3	**Susceptible**	14.92	10.67	4.00	1.50
	Moderately Susceptible	10.58	3.90	2.35	3.92
	Moderately Resistant	5.42	3.08	3.42	1.42
4	**Susceptible**	5.08	0.21	0.26	0.28
	Moderately Susceptible	3.71	0.04	0.01	0.00
	Moderately Resistant	1.06	0.00	0.08	0.00
5	**Susceptible**	6.51	1.47	0.12	0.02
	Moderately Susceptible	3.27	0.39	0.05	0.02
	Moderately Resistant	0.38	0.03	0.03	0.00
6	**Susceptible**	12.77	6.60	3.77	3.31
	Moderately Susceptible	8.00	4.71	3.06	2.40
	Moderately Resistant	1.65	0.43	0.16	0.04
	P Value	<.001			
	LSD	2.489			

*Appendix 2: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the interaction between site, variety and fungicide in 2016. *Data which did not have a reliable score due to a lack of green leaf area.*

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
1	**Susceptible**	21.20	5.35	1.58	0.43
	Moderately Susceptible	14.88	4.01	0.43	0.58
	Moderately Resistant	11.68	4.29	0.82	0.23
2	**Susceptible**	*	3.63	1.92	0.23
	Moderately Susceptible	6.06	6.07	2.97	1.20
	Moderately Resistant	2.75	0.83	0.50	0.25
3	**Susceptible**	*	40.92	24.42	12.92
	Moderately Susceptible	*	16.46	13.04	17.17
	Moderately Resistant	33.08	13.08	10.58	13.17
4	**Susceptible**	44.75	4.67	1.06	0.67
	Moderately Susceptible	24.08	1.64	0.18	0.25
	Moderately Resistant	13.00	0.60	0.12	0.13
5	**Susceptible**	42.84	4.22	1.76	0.30
	Moderately Susceptible	18.38	2.02	1.09	0.18
	Moderately Resistant	4.64	1.05	0.59	0.05
6	**Susceptible**	60.40	31.48	14.71	11.00
	Moderately Susceptible	54.47	44.54	19.77	9.27
	Moderately Resistant	10.23	7.24	4.79	4.60
	P Value	<.001			
	LSD	7.051			

Appendix 3: Average yield (t/ha) for the interaction between site, variety and fungicide in 2016.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
1	**Susceptible**	9.75	10.81	11.16	11.48
	Moderately Susceptible	9.48	10.53	10.60	10.81
	Moderately Resistant	9.33	9.57	10.36	10.22
2	**Susceptible**	4.15	3.97	5.16	5.38
	Moderately Susceptible	4.35	4.69	5.36	5.47
	Moderately Resistant	4.82	5.63	5.73	5.95
3	**Susceptible**	8.28	9.67	10.24	11.13
	Moderately Susceptible	8.77	9.87	10.10	10.33
	Moderately Resistant	8.66	9.28	9.74	9.99
6	**Susceptible**	8.76	9.67	10.15	10.58
	Moderately Susceptible	8.97	9.27	10.38	10.53
	Moderately Resistant	10.76	11.37	11.28	11.37
	P Value	<.001			
	LSD	1.006			

*Appendix 4: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the interaction between site, variety and fungicide in 2017. *Data which did not have a reliable score due to a lack of green leaf area.*

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
7	**Susceptible**	*	5.58	0.75	0.26
	Moderately Susceptible	39.51	1.11	0.38	0.04
	Moderately Resistant	20.56	1.12	0.33	0.10
8	**Susceptible**	16.50	4.54	2.92	1.92
	Moderately Susceptible	10.13	5.00	2.08	1.08
	Moderately Resistant	6.25	2.08	1.54	1.25
9	**Susceptible**	4.83	2.25	2.00	1.83
	Moderately Susceptible	5.77	1.00	0.92	0.92
	Moderately Resistant	3.92	1.92	1.42	0.42
10	**Susceptible**	12.49	2.18	0.33	0.37
	Moderately Susceptible	10.50	6.17	0.19	0.21
	Moderately Resistant	5.42	0.84	0.33	0.48
12	**Susceptible**	21.85	5.29	4.69	3.31
	Moderately Susceptible	12.02	4.46	4.44	3.23
	Moderately Resistant	5.85	1.96	2.04	1.96
	P Value	<.001			
	LSD	3.470			

*Appendix 5: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the interaction between site, sowing date, variety and fungicide in 2017. *Data which did not have a reliable score due to a lack of green leaf area.*

			Fungicide			
Site Number	**Sowing**	**Variety**	**Untreated**	**Low**	**Medium**	**High**
8	**Early**	**Susceptible**	*	7.63	6.17	3.73
		Moderately Susceptible	*	6.70	6.89	4.89
		Moderately Resistant	6.02	10.50	6.50	8.00
	Late	**Susceptible**	*	6.76	3.17	0.92
		Moderately Susceptible	10.05	3.67	2.01	0.67
		Moderately Resistant	7.33	6.67	3.87	2.50
9	**Early**	**Susceptible**	*	5.21	4.39	3.83
		Moderately Susceptible	20.58	5.67	2.67	1.50
		Moderately Resistant	10.50	1.67	0.67	2.50
	Late	**Susceptible**	5.43	1.45	0.74	0.00
		Moderately Susceptible	2.50	1.00	0.67	1.17
		Moderately Resistant	2.50	0.33	0.00	0.00
11	**Early**	**Susceptible**	*	24.19	9.89	7.50
		Moderately Susceptible	*	18.31	6.30	6.98
		Moderately Resistant	20.36	3.51	1.73	0.89
	Late	**Susceptible**	*	14.13	4.05	2.80
		Moderately Susceptible	*	8.88	1.47	1.80
		Moderately Resistant	14.42	1.48	0.30	0.45
12	**Early**	**Susceptible**	49.67	10.21	7.21	5.62
		Moderately Susceptible	33.71	9.17	6.25	5.42
		Moderately Resistant	21.37	5.96	5.33	4.54
	Late	**Susceptible**	39.84	8.29	6.21	4.92
		Moderately Susceptible	25.42	7.75	4.58	4.83
		Moderately Resistant	15.17	6.58	4.46	4.37
		P Value	<.001			
		LSD	5.545			

Appendix 6: Average yield (t/ha) for the interaction between site, variety and fungicide in 2017.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
7	**Susceptible**	8.17	9.40	9.73	9.97
	Moderately Susceptible	8.37	9.28	9.41	9.54
	Moderately Resistant	8.63	9.41	9.41	9.43
8	**Susceptible**	7.52	8.62	9.08	9.57
	Moderately Susceptible	8.06	8.54	8.12	8.59
	Moderately Resistant	7.33	7.98	8.31	8.06
9	**Susceptible**	9.57	10.96	10.81	10.70
	Moderately Susceptible	8.80	10.60	10.56	9.61
	Moderately Resistant	9.14	10.49	10.75	10.61
10	**Susceptible**	10.76	11.57	12.07	12.01
	Moderately Susceptible	10.82	10.89	11.27	11.53
	Moderately Resistant	9.63	10.29	10.43	10.73
11	**Susceptible**	7.18	8.88	10.21	9.93
	Moderately Susceptible	8.00	9.99	10.54	10.50
	Moderately Resistant	9.40	10.26	10.31	10.26
12	**Susceptible**	9.17	11.52	11.99	12.25
	Moderately Susceptible	10.59	12.17	12.24	12.32
	Moderately Resistant	10.95	11.52	11.40	11.60
	P Value	<.001			
	LSD	0.815			

Appendix 7: Average specific weight (kg/hl) for the interaction between site, variety and fungicide in 2017.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
7	**Santiago**	68.05	69.19	69.53	69.61
	JB Diego	70.59	71.52	71.21	71.26
	Revelation	69.61	69.69	70.05	69.58
8	**Santiago**	68.83	71.34	72.48	72.45
	JB Diego	75.08	75.36	75.59	75.48
	Revelation	70.61	72.31	71.95	71.88
9	**Santiago**	70.11	71.78	72.01	72.12
	JB Diego	73.04	75.28	74.96	74.51
	Revelation	70.49	71.23	71.47	71.53
10	**Santiago**	66.45	67.67	67.83	66.96
	JB Diego	69.62	69.53	68.80	69.36
	Revelation	65.84	65.73	66.36	66.18
	P Value	<.001			
	LSD	1.010			

Appendix 8: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the interaction between site, variety and fungicide in 2018.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
13	**Susceptible**	73.23	12.31	31.55	13.09
	Moderately Susceptible	38.05	4.64	11.36	3.84
	Moderately Resistant	21.31	2.7	4.89	1.51
14	**Susceptible**	6.83	1.21	0.27	0.47
	Moderately Susceptible	4.25	2.92	0.20	0.14
	Moderately Resistant	2.79	0.48	0.68	0.96
15	**Susceptible**	9.11	2.68	3.00	3.08
	Moderately Susceptible	5.10	3.08	3.51	4.08
	Moderately Resistant	2.92	3.55	3.83	2.93
17	**Susceptible**	44.05	13.83	7.36	6.99
	Moderately Susceptible	38.80	6.83	2.96	1.47
	Moderately Resistant	13.29	2.10	0.00	0.00
18	**Susceptible**	16.73	7.17	5.35	5.81
	Moderately Susceptible	17.44	7.50	5.52	6.83
	Moderately Resistant	4.44	2.42	1.77	1.83
	P Value	<.001			
	LSD	5.115			

*Appendix 9: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the interaction between site, sowing date, variety and fungicide in 2018. *Data which did not have a reliable score due to a lack of green leaf area.*

			Fungicide			
Site Number	**Sowing**	**Variety**	**Untreated**	**Low**	**Medium**	**High**
14	**Early**	**Susceptible**	*	3.83	1.17	0.83
		Moderately Susceptible	*	2.00	0.00	0.33
		Moderately Resistant	6.50	1.33	0.83	0.83
	Late	**Susceptible**	*	8.17	4.50	5.17
		Moderately Susceptible	*	5.96	1.53	2.17
		Moderately Resistant	4.33	2.50	0.50	0.00
15	**Early**	**Susceptible**	22.33	2.67	1.67	2.50
		Moderately Susceptible	7.50	2.50	2.00	1.50
		Moderately Resistant	3.83	3.33	2.83	2.33
	Late	**Susceptible**	13.81	6.47	6.17	7.17
		Moderately Susceptible	14.22	6.50	3.26	6.50
		Moderately Resistant	7.33	5.34	3.33	3.86
16	**Early**	**Susceptible**	2.08	0.25	0.00	0.00
		Moderately Susceptible	0.50	0.17	0.02	0.00
		Moderately Resistant	0.42	0.08	0.00	0.00
	Late	**Susceptible**	0.12	0.00	0.00	0.00
		Moderately Susceptible	0.33	0.97	0.00	0.00
		Moderately Resistant	0.00	0.00	0.00	0.00
18	**Early**	**Susceptible**	10.33	5.67	3.58	3.29
		Moderately Susceptible	15.33	6.29	3.67	7.00
		Moderately Resistant	4.96	2.71	2.58	2.33
	Late	**Susceptible**	5.42	2.67	2.50	2.62
		Moderately Susceptible	8.50	6.83	3.33	4.08
		Moderately Resistant	2.33	1.92	2.29	1.79
		P Value	0.003			
		LSD	3.33			

Appendix 10: Average yield (t/ha) for the interaction between site, variety and fungicide in 2018.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
13	**Susceptible**	9.89	11.29	11.05	11.59
	Moderately Susceptible	10.05	10.81	10.83	10.93
	Moderately Resistant	9.95	10.64	10.69	10.84
14	**Susceptible**	8.93	9.52	10.18	10.12
	Moderately Susceptible	9.24	8.81	9.57	9.68
	Moderately Resistant	9.66	9.97	10.08	10.03
15	**Susceptible**	11.49	11.74	12.35	11.97
	Moderately Susceptible	10.02	10.55	10.94	10.49
	Moderately Resistant	10.36	10.80	10.83	10.83
16	**Susceptible**	8.86	8.97	9.12	9.13
	Moderately Susceptible	8.76	8.79	8.97	9.05
	Moderately Resistant	8.54	8.83	8.92	9.18
18	**Susceptible**	10.91	11.37	12.27	12.12
	Moderately Susceptible	10.28	12.50	12.72	12.46
	Moderately Resistant	11.56	12.31	11.86	12.65
	P Value	<.001			
	LSD	0.554			

Appendix 11: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the interaction between site, sowing date, variety and fungicide in 2019.

			Fungicide			
Site Number	**Sowing**	**Variety**	**Untreated**	**Low**	**Medium**	**High**
19	**Early**	**Susceptible**	57.50	20.03	9.53	9.23
		Moderately Susceptible	26.20	6.67	4.00	2.53
		Moderately Resistant	7.40	2.50	1.37	1.67
	Late	**Susceptible**	28.93	3.33	1.47	1.33
		Moderately Susceptible	5.90	1.23	0.40	0.17
		Moderately Resistant	3.03	0.80	0.33	0.30
21	**Early**	**Susceptible**	2.83	0.33	0.07	0.00
		Moderately Susceptible	0.07	0.00	0.00	0.00
		Moderately Resistant	0.33	0.17	0.00	0.00
	Late	**Susceptible**	1.50	1.00	0.07	0.33
		Moderately Susceptible	0.00	0.00	0.00	0.00
		Moderately Resistant	0.00	0.00	0.00	0.00
		P Value	0.046			
		LSD	4.604			

Appendix 12: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the interaction between site, variety and fungicide in 2019.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
19	**Susceptible**	63.08	43.77	22.68	17.37
	Moderately Susceptible	57.30	19.78	6.73	3.83
	Moderately Resistant	35.92	8.27	2.50	2.58
20	**Susceptible**	3.67	0.00	0.00	0.00
	Moderately Susceptible	1.67	0.50	0.00	0.00
	Moderately Resistant	0.00	0.00	0.17	0.00
21	**Susceptible**	4.83	0.78	0.17	0.00
	Moderately Susceptible	0.65	0.12	0.00	0.05
	Moderately Resistant	0.20	0.00	0.00	0.00
22	**Susceptible**	64.39	43.47	18.10	13.94
	Moderately Susceptible	46.12	34.44	13.17	10.07
	Moderately Resistant	62.37	29.04	12.95	12.79
	P Value	0.015			
	LSD	9.200			

Appendix 13: Average yield (t/ha), for the interaction of site, variety and fungicide in 2019.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
19	**Susceptible**	6.12	8.66	10.41	10.65
	Moderately Susceptible	8.25	10.48	11.11	11.69
	Moderately Resistant	10.43	12.03	12.46	12.45
20	**Susceptible**	10.11	11.19	11.44	11.69
	Moderately Susceptible	9.79	9.31	9.91	10.36
	Moderately Resistant	10.24	10.31	10.45	10.93
21	**Susceptible**	10.00	11.31	11.68	11.74
	Moderately Susceptible	11.41	11.85	11.84	11.34
	Moderately Resistant	11.93	12.47	12.37	11.71
22	**Susceptible**	9.81	10.72	10.92	11.00
	Moderately Susceptible	9.63	10.81	10.29	10.71
	Moderately Resistant	9.45	10.79	11.37	10.93
	P Value	<.001			
	LSD	0.689			

Appendix 14: Average specific weight (kg/hl) for the interaction between site, variety and fungicide in 2019.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
19	**Santiago**	62.72	67.83	69.59	69.93
	Hardwicke	68.00	71.24	72.36	73.05
	Graham	72.53	72.89	73.98	73.58
20	**Santiago**	72.66	73.77	73.87	73.48
	Hardwicke	74.93	74.93	75.09	75.32
	Graham	75.61	75.59	76.10	75.45
21	**Santiago**	66.18	68.55	67.55	68.01
	Hardwicke	71.71	71.99	71.44	71.08
	Graham	72.00	71.82	71.70	71.34
	P Value	0.001			
	LSD	1.212			

Appendix 15: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the interaction between site and fungicide in 2020.

	Fungicide			
Site Number	**Untreated**	**Low**	**Medium**	**High**
24	36.76	26.61	17.56	8.44
25	9.64	1.58	1.5	0.14
P Value	<.001			
LSD	4.697			

*Appendix 16: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the interaction between site, variety and fungicide across all sites. *Data which did not have a reliable score due to a lack of green leaf area.*

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
1	**Susceptible**	7.40	1.77	1.12	0.80
	Moderately Susceptible	4.43	1.37	0.87	0.47
	Moderately Resistant	6.40	1.45	1.42	0.78
2	**Susceptible**	*	0.87	0.00	0.00
	Moderately Susceptible	7.77	2.99	1.04	2.94
	Moderately Resistant	0.67	0.58	0.17	0.83
3	**Susceptible**	14.67	11.33	4.83	1.33
	Moderately Susceptible	6.17	2.83	3.58	2.00
	Moderately Resistant	4.83	1.83	2.83	1.50
4	**Susceptible**	5.75	0.22	0.28	0.23
	Moderately Susceptible	3.50	0.05	0.02	0.00
	Moderately Resistant	0.83	0.00	0.00	0.00
5	**Susceptible**	7.14	1.95	0.15	0.03
	Moderately Susceptible	2.92	0.35	0.07	0.03
	Moderately Resistant	0.37	0.00	0.07	0.00
6	**Susceptible**	13.71	7.62	4.00	3.37
	Moderately Susceptible	7.91	5.33	2.83	2.83
	Moderately Resistant	1.88	0.43	0.30	0.00

7	**Susceptible**	*	4.31	0.49	0.14
	Moderately Susceptible	36.16	0.20	0.21	0.04
	Moderately Resistant	19.50	1.22	0.42	0.09
8	**Susceptible**	17.83	4.58	1.67	2.17
	Moderately Susceptible	12.50	4.67	1.33	1.17
	Moderately Resistant	8.83	2.50	0.75	0.83
9	**Susceptible**	5.17	2.67	2.83	2.33
	Moderately Susceptible	6.92	1.00	1.00	1.17
	Moderately Resistant	5.33	2.50	1.33	0.17
10	**Susceptible**	12.46	2.50	0.57	0.12
	Moderately Susceptible	13.47	7.42	0.20	0.08
	Moderately Resistant	5.67	1.50	0.13	0.03
12	**Susceptible**	27.12	5.25	5.46	3.79
	Moderately Susceptible	10.00	4.33	4.92	3.58
	Moderately Resistant	6.21	1.92	2.08	1.71
13	**Susceptible**	73.26	15.01	35.20	14.94
	Moderately Susceptible	40.84	5.21	11.43	2.80
	Moderately Resistant	24.07	2.82	5.67	1.47
14	**Susceptible**	7.83	1.00	0.42	0.37
	Moderately Susceptible	5.83	3.17	0.28	0.00
	Moderately Resistant	4.25	0.75	0.87	0.42
15	**Susceptible**	10.76	2.76	3.50	3.17
	Moderately Susceptible	5.83	3.17	4.11	4.50
	Moderately Resistant	2.33	4.19	3.83	3.36
17	**Susceptible**	43.52	14.23	9.88	8.51
	Moderately Susceptible	40.55	5.81	4.95	2.45
	Moderately Resistant	17.87	3.46	1.65	0.89
18	**Susceptible**	14.87	7.25	4.25	5.33
	Moderately Susceptible	16.92	8.17	5.04	8.04
	Moderately Resistant	5.33	2.50	1.67	1.67
19	**Susceptible**	43.22	11.68	5.50	5.28
	Moderately Susceptible	16.05	3.95	2.20	1.35
	Moderately Resistant	5.22	1.65	0.85	0.98
21	**Susceptible**	2.17	0.67	0.07	0.17
	Moderately Susceptible	0.03	0.00	0.00	0.00
	Moderately Resistant	0.17	0.08	0.00	0.00
24	**Susceptible**	14.83	7.33	3.00	1.00
	Moderately Susceptible	5.83	4.17	4.33	1.17
	Moderately Resistant	3.33	1.17	2.17	0.67
25	**Susceptible**	1.08	0.83	0.00	0.25
	Moderately Susceptible	1.83	0.75	0.33	0.08
	Moderately Resistant	0.50	0.25	0.00	0.00
	P Value	<.001			
	LSD	4.799			

*Appendix 17: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the interaction between site, sowing date, variety and fungicide across all seasons. *Data which did not have a reliable score due to a lack of green leaf area.*

			Fungicide			
Site Number	**Sowing**	**Variety**	**Untreated**	**Low**	**Medium**	**High**
1	**Early**	**Susceptible**	30.53	7.48	3.17	0.88
		Moderately Susceptible	18.67	5.92	0.92	0.53
		Moderately Resistant	17.43	9.77	1.53	0.18
	Late	**Susceptible**	11.58	1.20	0.02	0.18
		Moderately Susceptible	6.05	0.80	0.27	0.03
		Moderately Resistant	2.83	1.32	0.03	0.35
2	**Early**	**Susceptible**	*	1.67	1.67	0.67
		Moderately Susceptible	9.27	5.33	4.00	2.33
		Moderately Resistant	3.33	0.67	1.33	0.67
	Late	**Susceptible**	*	3.44	0.33	0.00
		Moderately Susceptible	4.33	4.33	2.33	0.33
		Moderately Resistant	2.00	0.67	0.00	0.00
3	**Early**	**Susceptible**	*	37.33	19.67	15.00
		Moderately Susceptible	*	22.87	11.37	6.67
		Moderately Resistant	40.67	13.67	12.00	14.33
	Late	**Susceptible**	*	52.33	33.00	19.67
		Moderately Susceptible	*	11.67	15.00	17.67
		Moderately Resistant	23.67	12.00	9.00	6.33
4	**Early**	**Susceptible**	41.33	2.67	0.67	1.00
		Moderately Susceptible	28.33	0.50	0.00	0.00
		Moderately Resistant	9.67	0.03	0.00	0.00
	Late	**Susceptible**	49.33	0.87	1.83	0.03
		Moderately Susceptible	23.67	0.07	0.40	0.33
		Moderately Resistant	19.67	0.33	0.50	0.17
5	**Early**	**Susceptible**	25.43	2.80	2.03	0.30
		Moderately Susceptible	10.43	1.27	1.12	0.23
		Moderately Resistant	4.53	1.66	1.77	0.03
	Late	**Susceptible**	64.86	5.23	1.40	0.17
		Moderately Susceptible	26.44	2.33	0.55	0.03
		Moderately Resistant	3.55	0.43	0.13	0.07
6	**Early**	**Susceptible**	48.67	23.58	14.67	9.75
		Moderately Susceptible	55.72	57.08	28.42	8.50
		Moderately Resistant	11.67	7.22	3.60	3.42
	Late	**Susceptible**	61.92	35.58	17.83	8.50
		Moderately Susceptible	41.75	38.67	18.83	10.33
		Moderately Resistant	9.17	8.25	5.75	6.50
8	**Early**	**Susceptible**	*	10.31	4.00	6.00
		Moderately Susceptible	*	7.05	5.33	4.71
		Moderately Resistant	4.98	10.00	7.00	10.00
	Late	**Susceptible**	*	5.33	2.00	0.67
		Moderately Susceptible	9.64	2.33	2.33	1.33
		Moderately Resistant	8.33	6.33	3.00	2.67

9	**Early**	**Susceptible**	14.33	4.67	4.33	5.67
		Moderately Susceptible	15.48	2.67	2.67	2.33
		Moderately Resistant	16.67	1.00	0.00	3.00
	Late	**Susceptible**	1.67	0.67	0.67	0.00
		Moderately Susceptible	1.67	0.00	0.67	1.67
		Moderately Resistant	2.33	0.67	0.00	0.00
11	**Early**	**Susceptible**	*	26.17	12.55	8.37
		Moderately Susceptible	*	18.46	5.44	6.08
		Moderately Resistant	24.24	3.95	0.64	0.48
	Late	**Susceptible**	*	12.59	4.52	4.23
		Moderately Susceptible	*	9.91	1.04	1.59
		Moderately Resistant	15.83	1.40	0.27	0.79
12	**Early**	**Susceptible**	51.33	10.08	6.75	6.17
		Moderately Susceptible	33.00	10.50	7.58	5.25
		Moderately Resistant	26.83	6.08	5.42	4.75
	Late	**Susceptible**	33.00	10.17	6.42	5.33
		Moderately Susceptible	26.17	8.00	4.92	5.08
		Moderately Resistant	16.67	7.50	4.58	4.08
14	**Early**	**Susceptible**	*	5.00	1.67	0.67
		Moderately Susceptible	*	2.33	0.00	0.67
		Moderately Resistant	9.00	2.67	0.67	1.00
	Late	**Susceptible**	*	8.67	5.00	6.33
		Moderately Susceptible	*	1.02	1.08	4.20
		Moderately Resistant	3.67	2.00	0.67	0.00
15	**Early**	**Susceptible**	33.33	3.67	2.00	2.00
		Moderately Susceptible	9.33	3.00	2.67	1.33
		Moderately Resistant	4.67	3.33	3.33	2.67
	Late	**Susceptible**	16.34	4.84	10.00	4.00
		Moderately Susceptible	18.33	7.33	4.14	3.33
		Moderately Resistant	9.00	7.64	4.33	5.14
16	**Early**	**Susceptible**	2.33	0.33	0.00	0.00
		Moderately Susceptible	0.67	0.33	0.00	0.00
		Moderately Resistant	0.83	0.00	0.00	0.00
	Late	**Susceptible**	0.17	0.00	0.00	0.00
		Moderately Susceptible	0.00	0.00	0.00	0.00
		Moderately Resistant	0.00	0.00	0.00	0.00
18	**Early**	**Susceptible**	9.67	6.00	2.33	2.67
		Moderately Susceptible	15.08	7.50	2.17	8.33
		Moderately Resistant	5.25	1.83	3.75	2.33
	Late	**Susceptible**	4.67	3.17	2.83	1.92
		Moderately Susceptible	9.92	7.67	1.92	4.75
		Moderately Resistant	3.08	2.00	3.00	2.58
19	**Early**	**Susceptible**	66.33	59.17	39.00	30.53
		Moderately Susceptible	62.83	36.73	11.67	6.40
		Moderately Resistant	50.67	14.50	3.97	4.73

	Late	**Susceptible**	59.83	28.37	6.37	4.20
		Moderately Susceptible	51.77	2.83	1.80	1.27
		Moderately Resistant	21.17	2.03	1.03	0.43
20	**Early**	**Susceptible**	7.00	0.00	0.00	0.00
		Moderately Susceptible	3.00	0.67	0.00	0.00
		Moderately Resistant	0.00	0.00	0.33	0.00
	Late	**Susceptible**	0.33	0.00	0.00	0.00
		Moderately Susceptible	0.33	0.33	0.00	0.00
		Moderately Resistant	0.00	0.00	0.00	0.00
21	**Early**	**Susceptible**	5.67	1.17	0.17	0.00
		Moderately Susceptible	0.47	0.00	0.00	0.03
		Moderately Resistant	0.40	0.00	0.00	0.00
	Late	**Susceptible**	4.00	0.40	0.17	0.00
		Moderately Susceptible	0.83	0.23	0.00	0.07
		Moderately Resistant	0.00	0.00	0.00	0.00
22	**Early**	**Susceptible**	68.40	37.62	17.38	15.48
		Moderately Susceptible	49.00	26.72	13.04	11.85
		Moderately Resistant	75.33	32.09	15.28	11.30
	Late	**Susceptible**	60.38	49.32	18.83	12.40
		Moderately Susceptible	43.24	42.15	13.30	8.29
		Moderately Resistant	49.42	26.00	10.61	14.29
24	**Early**	**Susceptible**	52.37	30.00	25.00	11.67
		Moderately Susceptible	33.79	40.00	25.00	11.67
		Moderately Resistant	40.61	35.67	20.00	10.00
	Late	**Susceptible**	43.33	20.00	14.33	5.00
		Moderately Susceptible	31.67	17.33	11.67	7.33
		Moderately Resistant	29.83	16.67	9.33	5.00
25	**Early**	**Susceptible**	16.00	0.83	2.00	0.00
		Moderately Susceptible	15.67	3.50	2.17	0.17
		Moderately Resistant	4.17	0.50	0.83	0.00
	Late	**Susceptible**	8.33	2.50	1.67	0.50
		Moderately Susceptible	12.00	1.67	1.50	0.17
		Moderately Resistant	1.67	0.50	0.83	0.00
		P Value	0.002			
		LSD	9.963			

Appendix 18: Average yield (t/ha) for the interaction between site, variety and fungicide across seasons.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
1	**Susceptible**	9.96	10.88	11.51	11.98
	Moderately Susceptible	9.61	10.47	10.74	11.05
	Moderately Resistant	9.79	9.86	10.12	10.21
2	**Susceptible**	4.52	3.87	5.61	5.31
	Moderately Susceptible	4.71	4.72	5.50	5.55
	Moderately Resistant	4.99	5.74	5.70	5.98
3	**Susceptible**	8.42	9.73	10.39	11.30
	Moderately Susceptible	9.06	10.16	10.43	10.53
	Moderately Resistant	9.03	9.55	9.93	10.17
6	**Susceptible**	9.23	10.07	10.38	10.89
	Moderately Susceptible	9.49	9.80	10.52	11.00
	Moderately Resistant	10.82	11.17	11.29	11.17
7	**Susceptible**	8.20	9.80	10.04	10.22
	Moderately Susceptible	8.64	9.58	9.44	9.28
	Moderately Resistant	8.90	9.55	9.51	9.66
8	**Susceptible**	7.57	8.85	9.33	9.43
	Moderately Susceptible	8.00	8.16	7.66	8.91
	Moderately Resistant	7.67	8.28	8.45	8.05
9	**Susceptible**	9.53	11.16	10.89	10.80
	Moderately Susceptible	8.96	10.80	10.74	10.20
	Moderately Resistant	9.13	10.78	10.75	10.88
10	**Susceptible**	10.54	11.62	12.08	11.98
	Moderately Susceptible	10.67	11.07	11.09	11.61
	Moderately Resistant	9.46	10.32	10.37	10.85
11	**Susceptible**	7.52	8.69	10.51	10.10
	Moderately Susceptible	8.19	10.66	11.02	10.89
	Moderately Resistant	9.59	10.66	11.15	10.54
12	**Susceptible**	9.55	11.72	12.23	12.26
	Moderately Susceptible	10.93	12.73	12.85	12.71
	Moderately Resistant	10.94	11.98	11.20	12.00
13	**Susceptible**	9.84	11.36	11.20	11.66
	Moderately Susceptible	10.26	10.87	10.94	11.20
	Moderately Resistant	10.05	10.72	10.82	10.86
14	**Susceptible**	9.21	9.94	10.34	10.24
	Moderately Susceptible	9.65	8.30	9.76	10.16
	Moderately Resistant	10.00	10.25	10.30	9.83
15	**Susceptible**	11.66	12.44	12.46	12.61
	Moderately Susceptible	10.00	11.28	10.86	11.09
	Moderately Resistant	10.49	11.18	11.00	11.54
16	**Susceptible**	8.89	9.03	9.13	9.30
	Moderately Susceptible	8.75	8.76	8.98	9.12
	Moderately Resistant	8.92	8.93	9.04	9.14

18	**Susceptible**	11.19	11.58	12.88	12.13
	Moderately Susceptible	10.37	12.63	13.31	12.46
	Moderately Resistant	11.52	13.31	11.92	13.04
19	**Susceptible**	6.12	8.66	10.41	10.65
	Moderately Susceptible	8.25	10.48	11.11	11.69
	Moderately Resistant	10.43	12.03	12.46	12.45
20	**Susceptible**	10.11	11.19	11.44	11.69
	Moderately Susceptible	9.79	9.31	9.91	10.36
	Moderately Resistant	10.24	10.31	10.45	10.93
21	**Susceptible**	10.00	11.31	11.68	11.74
	Moderately Susceptible	11.41	11.85	11.84	11.35
	Moderately Resistant	11.93	12.47	12.37	11.71
22	**Susceptible**	9.81	10.72	10.92	11.00
	Moderately Susceptible	9.63	10.81	10.29	10.71
	Moderately Resistant	9.45	10.79	11.37	10.93
24	**Susceptible**	10.05	10.57	10.82	10.91
	Moderately Susceptible	10.23	11.19	11.29	11.38
	Moderately Resistant	10.18	11.36	11.10	11.64
25	**Susceptible**	9.23	10.31	10.32	10.88
	Moderately Susceptible	9.17	10.49	10.48	11.02
	Moderately Resistant	9.82	10.18	10.67	10.62
	P Value	<.001			
	LSD	0.848			

*Appendix 19: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the interaction between site, variety and fungicide in low pressure sites. *Data which did not have a reliable score due to a lack of green leaf area.*

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
2	**Susceptible**	*	1.42	1.76	0.55
	Moderately Susceptible	6.80	4.83	3.17	1.33
	Moderately Resistant	2.67	0.67	0.67	0.33
5	**Susceptible**	45.15	4.02	1.72	0.23
	Moderately Susceptible	18.44	1.80	0.84	0.13
	Moderately Resistant	4.04	1.05	0.95	0.05
14	**Susceptible**	*	6.83	3.33	3.50
	Moderately Susceptible	*	3.24	0.65	1.48
	Moderately Resistant	6.33	2.33	0.67	0.50
15	**Susceptible**	24.84	4.25	6.00	3.00
	Moderately Susceptible	13.83	5.17	3.40	2.33
	Moderately Resistant	6.83	5.49	3.83	3.90
16	**Susceptible**	1.25	0.17	0.00	0.00
	Moderately Susceptible	0.33	0.17	0.00	0.00
	Moderately Resistant	0.42	0.00	0.00	0.00
18	**Susceptible**	7.17	4.58	2.58	2.29
	Moderately Susceptible	12.50	7.58	2.04	6.54
	Moderately Resistant	4.17	1.92	3.38	2.46
20	**Susceptible**	3.67	0.00	0.00	0.00
	Moderately Susceptible	1.67	0.50	0.00	0.00
	Moderately Resistant	0.00	0.00	0.17	0.00
21	**Susceptible**	4.83	0.78	0.17	0.00
	Moderately Susceptible	0.65	0.12	0.00	0.05
	Moderately Resistant	0.20	0.00	0.00	0.00
	P Value	<.001			
	LSD	2.852			

Appendix 20: Average yield (t/ha) for the interaction between site, variety and fungicide for low pressure sites.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
2	**Susceptible**	4.68	4.00	5.69	5.51
	Moderately Susceptible	4.56	4.28	5.41	5.40
	Moderately Resistant	4.99	5.74	5.70	5.98
14	**Susceptible**	9.21	9.94	10.34	10.24
	Moderately Susceptible	9.85	8.28	9.75	10.30
	Moderately Resistant	10.00	10.25	10.30	9.83
15	**Susceptible**	11.66	12.44	12.46	12.61
	Moderately Susceptible	10.00	11.28	10.86	11.09
	Moderately Resistant	10.49	11.18	11.00	11.54
16	**Susceptible**	8.89	9.03	9.13	9.30
	Moderately Susceptible	8.75	8.76	8.98	9.12
	Moderately Resistant	8.92	8.93	9.04	9.14
18	**Susceptible**	11.19	11.58	12.88	12.13
	Moderately Susceptible	10.37	12.63	13.31	12.46
	Moderately Resistant	11.52	13.31	11.92	13.04
20	**Susceptible**	10.11	11.19	11.44	11.69
	Moderately Susceptible	9.79	9.31	9.91	10.36
	Moderately Resistant	10.24	10.31	10.45	10.93
21	**Susceptible**	10.00	11.31	11.68	11.74
	Moderately Susceptible	11.41	11.85	11.84	11.34
	Moderately Resistant	11.93	12.47	12.37	11.71
	P Value	<.001			
	LSD	0.844			

Appendix 21: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the interaction between site and fungicide in medium pressure sites.

	Fungicide			
Site Number	**Untreated**	**Low**	**Medium**	**High**
1	6.08	1.53	1.13	0.68
4	3.36	0.09	0.10	0.08
8	13.06	3.92	1.25	1.39
9	5.81	2.06	1.72	1.22
25	1.14	0.61	0.11	0.11
P Value	<.001			
LSD	2.15			

*Appendix 22: Average septoria severity (%) on leaf 2 at T2 + 6-8 weeks for the interaction between site, variety and fungicide in medium pressure sites. *Data which did not have a reliable score due to a lack of green leaf area.*

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
1	**Susceptible**	21.06	4.34	1.59	0.53
	Moderately Susceptible	12.36	3.36	0.59	0.28
	Moderately Resistant	10.13	5.54	0.78	0.27
4	**Susceptible**	45.33	1.77	1.25	0.52
	Moderately Susceptible	26.00	0.28	0.20	0.17
	Moderately Resistant	14.67	0.18	0.25	0.08
8	**Susceptible**	*	7.82	3.00	3.33
	Moderately Susceptible	8.50	4.67	3.83	3.02
	Moderately Resistant	6.66	8.17	5.00	6.33
9	**Susceptible**	8.00	2.67	2.50	2.83
	Moderately Susceptible	8.58	1.33	1.67	2.00
	Moderately Resistant	9.50	0.83	0.00	1.50
25	**Susceptible**	12.17	1.67	1.83	0.25
	Moderately Susceptible	13.83	2.58	1.83	0.17
	Moderately Resistant	2.92	0.50	0.83	0.00
	P Value	<.001			
	LSD	4.811			

Appendix 23: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the interaction between site, variety and fungicide in high pressure sites.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
3	**Susceptible**	14.67	11.33	4.83	1.33
	Moderately Susceptible	6.17	2.83	3.58	2.00
	Moderately Resistant	4.83	1.83	2.83	1.50
6	**Susceptible**	13.71	7.62	4.00	3.37
	Moderately Susceptible	7.91	5.33	2.83	2.83
	Moderately Resistant	1.87	0.43	0.31	0.00
12	**Susceptible**	27.12	5.25	5.46	3.79
	Moderately Susceptible	10.00	4.33	4.92	3.58
	Moderately Resistant	6.21	1.92	2.08	1.71
13	**Susceptible**	73.26	15.01	35.20	14.94
	Moderately Susceptible	40.84	5.21	11.43	2.80
	Moderately Resistant	24.07	2.82	5.67	1.47
19	**Susceptible**	43.22	11.68	5.50	5.28
	Moderately Susceptible	16.05	3.95	2.20	1.35
	Moderately Resistant	5.22	1.65	0.85	0.98
24	**Susceptible**	14.83	7.33	3.00	1.00
	Moderately Susceptible	5.83	4.17	4.33	1.17
	Moderately Resistant	3.33	1.17	2.17	0.67
	P Value	<.001			
	LSD	5.456			

Appendix 24: Average yield (t/ha) for the interaction between site, variety and fungicide in high pressure sites.

		Fungicide			
Site Number	**Variety**	**Untreated**	**Low**	**Medium**	**High**
3	**Susceptible**	8.42	9.73	10.39	11.30
	Moderately Susceptible	9.06	10.16	10.43	10.53
	Moderately Resistant	9.03	9.55	9.93	10.17
6	**Susceptible**	9.23	10.07	10.38	10.89
	Moderately Susceptible	9.49	9.80	10.52	11.00
	Moderately Resistant	10.82	11.17	11.29	11.17
11	**Susceptible**	7.52	8.69	10.51	10.10
	Moderately Susceptible	8.19	10.66	11.02	10.89
	Moderately Resistant	9.59	10.66	11.15	10.54
12	**Susceptible**	9.55	11.72	12.23	12.26
	Moderately Susceptible	10.93	12.73	12.85	12.71
	Moderately Resistant	10.94	11.98	11.20	12.00
13	**Susceptible**	9.84	11.36	11.20	11.66
	Moderately Susceptible	10.26	10.87	10.94	11.20
	Moderately Resistant	10.05	10.72	10.82	10.86
19	**Susceptible**	6.12	8.66	10.41	10.65
	Moderately Susceptible	8.25	10.48	11.11	11.69
	Moderately Resistant	10.43	12.03	12.46	12.45
22	**Susceptible**	9.81	10.72	10.92	11.00
	Moderately Susceptible	9.63	10.81	10.29	10.71
	Moderately Resistant	9.45	10.79	11.37	10.93
24	**Susceptible**	10.05	10.57	10.82	10.91
	Moderately Susceptible	10.23	11.19	11.29	11.38
	Moderately Resistant	10.18	11.36	11.10	11.64
	P Value	<.001			
	LSD	0.755			

Appendix 25: Average septoria severity (%) on leaf 3 at T2 + 2-3 weeks for the interaction between site and seed rate across all sites from 2016 to 2018.

Site Number	High seed rate	Low seed rate
1	2.36	2.57
2	1.93	1.35
3	4.77	6.09
4	0.91	0.88
5	1.09	0.96
6	4.15	3.67
7	6.84	10.05
8	4.90	4.31
9	2.68	1.85
10	3.64	2.94
12	6.36	5.49
13	19.39	17.02
14	2.10	1.44
15	4.26	3.55
17	12.71	10.04
18	6.75	7.05
P value	<.001	
LSD	2.366	

Appendix 26: Average yield (t/ha) for the interaction between site and seed rate across all sites from 2016 to 2018.

Site Number	High Seed Rate	Low Seed Rate
1	10.52	10.17
2	5.18	5.09
3	9.89	9.45
6	10.50	10.01
7	9.40	9.06
8	8.36	8.27
9	10.38	10.09
10	10.94	11.02
11	9.96	9.28
12	11.76	11.19
13	10.82	10.61
14	9.83	9.45
15	11.38	10.59
16	9.00	8.86
18	12.20	11.64
P value	<.001	
LSD	0.615	

Appendix 27: Average yield (t/ha) for the interaction between site, sowing date and seed rate across all sites from 2016 to 2018.

	Early Sown		Late Sown	
Site Number	**High Seed Rate**	**Low Seed Rate**	**High Seed Rate**	**Low Seed Rate**
1	9.90	9.40	11.13	10.93
2	4.77	4.59	5.58	5.58
3	9.85	9.27	9.94	9.64
6	9.83	9.07	11.17	10.95
7	9.30	9.02	9.50	9.09
8	8.48	8.24	8.23	8.31
9	10.50	10.05	10.26	10.13
10	11.05	11.08	10.83	10.96
11	9.96	8.70	9.95	9.87
12	11.61	10.71	11.90	11.68
13	11.05	10.81	10.58	10.41
14	9.93	9.76	9.74	9.13
15	11.28	10.34	11.48	10.85
16	9.15	8.92	8.84	8.80
18	12.39	11.48	12.00	11.80
P value	<.001			
LSD	0.857			