

Yield and grain quality losses in barley varieties infected with spot type net blotch (STNB)

Andrea Hills¹, Geoff Thomas² and Mark McLean³, Department of Primary Industries and Regional Development, Esperance ¹, South Perth², Western Australia and Department of Economic Development, Jobs, Transport and resources, Horsham³, Victoria

Key messages

- STNB disease severity was related to barley variety resistance rankings in untreated plots, Fathom (MR) generally had the lowest disease levels, then Compass (MRMS) while Granger (S), SY Rattler (SVS) and Hindmarsh (SVS) were the worst affected.
- Under high disease pressure conditions (sown onto infected stubble) all varieties had some level of yield response to fungicide control of STNB. Even Fathom, the variety currently most resistant to STNB had yield responses of 0-16%. Other varieties had yield responses of 0-36%. In high yielding situations, even low levels of STNB were worth controlling for grain yield and quality improvements, especially screenings.
- Seedling resistance was associated with slightly reduced STNB infection severity at grain filling, much greater gains were seen in varieties with adult resistance.
- In some situations, fungicide control of STNB reduced lodging and head loss in varieties prone to these problems.

Aims

This three year series of trials aimed to quantify losses in barley yield and quality from spot type net blotch (STNB) across a range of variety resistances in the Western Australian (WA) environment. These trials are a subset of a national series and varieties were selected based on their resistance profile.

Method

Small plot trials (10m x 1.5m) with 10 varieties (Table 1) in a split plot design with six replicates were sown on infected barley stubble in 2015 to 2017 in the medium (Wittenoom Hills and Cunderdin) and low (Nukarni) rainfall areas of WA and a range of disease severities resulted (Tables 1, 2). Disease control was applied to half of the plots as Systiva® seed dressing followed with foliar fungicide applications at stem elongation and flag leaf emergence. In 2017 at Wittenoom Hills, leaf rust appeared in July, so for experimental purposes 'untreated' plots received three foliar applications of a fungicide which is active on leaf rust while having minimal impact on STNB. This remedial treatment was effective on all varieties apart from Compass and Fathom which developed yield limiting levels of leaf rust (>5%); hence their 2017 grain yield data has been excluded from this analysis. Disease severity was assessed as percentage leaf area affected by STNB (%LAA) on the top 4 leaves, Flag leaf (F) to Flag -3 (F-3).

Grain yield was measured by machine harvest and subsamples taken for assessment of grain quality characteristics (screenings, grain weight, hectolitre weight, brightness and protein). At Wittenoom Hills, lodging scores were taken close to harvest and head loss assessments made by collecting and weighing heads on the ground in 1m paired rows at two locations per plot. Statistical comparisons were made using the 18th edition of Genstat (VSN International).

Table 1. Disease rankings of varieties and years of inclusion in the trial series.

Variety	Disease rating		Years included
	Seedling	Adult	
Compass ^(b)	MRMS	MSS	2015, 2016, 2017
Dash ^(b)	S	SVS	2015, 2016, 2017
Fathom ^(b)	MR	MRMS	2015, 2016, 2017
Granger ^(b)	S	SVS	2015, 2016, 2017
Hindmarsh ^(b)	SVS	SVS	2015, 2016, 2017
LaTrobe ^(b)	S	SVS	2015, 2016, 2017
Rosalind ^(b)	MS	S	- 2016, 2017
Scope ^(b)	MS	S	2015, 2016, 2017
Spartacus CL ^(b)	SVS	S	- 2016, 2017
SY Rattler ^(b)	S	SVS	2015, 2016, 2017

Table 2. Location, sowing date and the maximum average level of STNB observed in each trial at grain filling.

Year	Location	Sowing date	Maximum average STNB (%LAA F-1 to F-3)#
2015	Wittenoorn Hills	12-May	20
	Nukarni	11-May	32
2016	Wittenoorn Hills	12-May	14
	Nukarni	5-May	18
2017	Wittenoorn Hills	9-May	13*
	Cunderdin	18-May	28

*F to F-2

Results

Disease

Disease severity varied across sites and years with central region sites (Nukarni, Cunderdin) generally having higher infection levels than at the southern site (Wittenoorn Hills) (Tables 2, 3). The disease pressure was high in the Cunderdin trial and despite fungicide applications, some STNB developed in the 'STNB Controlled' treatments, averaging 9% leaf area affected (%LAA).

Table 3. Average severity of STNB on Flag to Flag-2 leaves (%LAA) during grain filling of ten varieties at six sites over three years where STNB was either left Untreated or Controlled with fungicides.

	Variety	(Average % LAA of F to F-2)						Average
		Wittenoorn Hills			Nukarni		Cunderdin	
		2015#	2016	2017	2015	2016	2017	
Untreated	Compass	5.1 d	4.6 g	0.8 f	15.7 c	12.7 b	14.5 c	8.9
	Dash	15.2 a	14.0 a	13.0 a	11.5 d	9.7 c	18.9 ab	13.7
	Fathom	1.3 e	1.6 h	0.6 f	9.8 d	6.7 c	9.9 d	5.0
	Granger	11.9 b	12.5 b	9.7 b	22.7 a	13.7 ab	22.2 a	15.4
	Hindmarsh	16.5 a	9.5 c	7.4 c	20.5 ab	12.4 b	19.2 a	14.3
	LaTrobe	8.5 c	8.0 d	5.4 d	15.6 c	12.3 b	18.2 bc	11.3
	Rosalind		6.5 ef	5.2 de		13.2 ab	18.8 ab	10.9
	Scope	8.4 c	6.1 f	4.9 e	17.3 bc	15.5 a	15.1 bc	11.2
	Spartacus CL		7.7 d	5.5 d		11.3 bc	18.8 ab	10.8
	SY Rattler	16.8 a	13.0 de	9.9 b	8.5 d	13.7 ab	20.1 a	13.7
	Average	10.5	8.4	6.2	15.2	12.1	17.6	11.7
Controlled	Compass	n/a	0.8 bc	0.9 cd*	7.0 ab	4.0 ab	7.4 bc	4.0
	Dash		2.2 a	1.9 b	5.4 b	3.0 ab	7.7 bc	4.0
	Fathom		0.1 c*	0.0 e*	4.6 b	3.1 ab*	6.0 c*	2.8
	Granger		1.9 bc	2.4 a	9.6 a	4.4 ab	14.1 a	6.5
	Hindmarsh		0.8 bc	1.0 c	6.9 ab	3.5 ab	8.7 bc	4.2
	LaTrobe		0.8 bc	0.5 d	5.2 b	2.8 ab	9.6 bc	3.8
	Rosalind		0.6 bc	0.5 d		4.8 ab	9.0 bc	3.7
	Scope		0.8 bc	0.9 cd	6.0 ab	3.0 ab	9.8 bc	4.1
	Spartacus CL		0.9 bc	0.7 cd		2.5 b	10.8 ab	3.7
	SY Rattler		2.3 a	1.6 b	5.7 b*	5.2 a	10.9 ab	5.1
	Average		1.1	1.0	6.3	3.6	9.4	4.3
p-values	Control		<.001	0.007	0.003	0.002	<.001	
	Variety	<.001	<.001	<.001	<.001	<.001	<.001	
	Control.Var		<.001	<.001	<.001	0.002	0.226	
Lsd (0.05)	Control		0.77	2.50	3.16	3.50	2.84	
	Variety	2.93	1.07	1.14	2.62	1.73	2.77	
	Control.Var		1.47	2.42	4.06	3.83	4.36	
	-same Fung		1.40	0.41	3.70	2.44	3.92	
cv%		6.6	11.5	15.2	16.7	21.2	6.1	

Letters indicate significantly different (0.05) STNB severity between varieties within fungicide treatments (Untreated / Controlled).

* In the Controlled columns, an asterisk indicates STNB severity in that variety did not respond significantly to fungicide application.

Fathom generally had the lowest STNB levels, then Compass while Granger, SY Rattler and Hindmarsh tended to be the worst affected from stem elongation (data not shown), through to grain filling (Table 3). There were differences in variety responses across regions, indicating that variety response can be influenced by environment. At the central region sites, Granger had the highest disease levels while in the south Dash and SY Rattler were worse than Granger. Fungicide control significantly reduced disease severity in the susceptible varieties in all trials; Fathom typically had low levels of disease in untreated plots and did not always respond to fungicides.

When varieties are grouped according to their seedling or adult resistance rating for STNB severity at grain filling (Figure 1), the downward trend in disease levels indicates that variety resistance remains an effective tool in reducing leaf infection, especially at adult growth stages where every step up in resistance rating decreased disease severity.

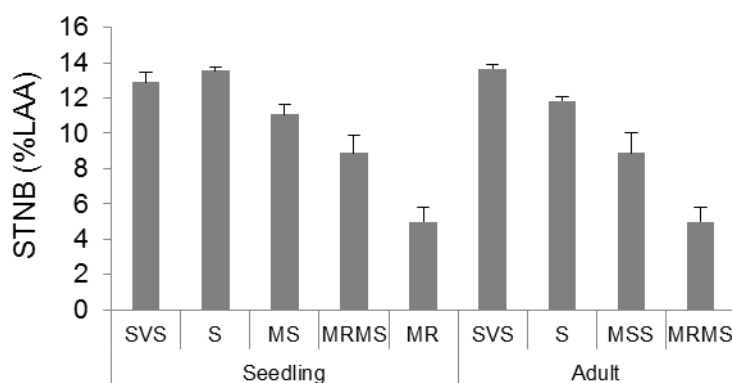


Figure 1. Average STNB severity (% LAA of Flag to Flag-2) at grain filling for varieties grouped according to their seedling or adult resistance rating (2018 Barley Variety Sowing Guide) with standard error bars.

Grain yield

There was a grain yield response to STNB control in five of six trials; in 2015 the Nukarni site did not receive sufficient spring rainfall to allow disease differences to be expressed in grain yield. In the other trials, the magnitude of responses to STNB control varied considerably across years and sites (Table 4). Dash and SY Rattler commonly had the greatest yield responses to disease control but other varieties varied markedly e.g. Hindmarsh.

Table 4. The grain yield response to STNB control (% increase over untreated yield) in ten varieties at six sites over 2015 – 2017. The variety average is calculated on responsive sites only (excludes Nukarni 2015).

Variety	Wittenoom Hills			Nukarni		Cunderdin	Average
	2015	2016	2017	2015	2016	2017	
Compass	18%	13%	n/a	3%	-1%	12%	9%
Dash	41%	23%	16%	17%	14%	34%	21%
Fathom	9%	6%	n/a	-5%	10%	16%	7%
Granger	15%	11%	8%	-3%	13%	15%	9%
Hindmarsh	36%	11%	7%	5%	3%	33%	12%
LaTrobe	24%	10%	10%	3%	6%	15%	10%
Rosalind	-	8%	8%	-	8%	33%	12%
Scope	17%	4%	4%	-1%	7%	36%	8%
Spartacus CL	-	9%	9%	-	8%	16%	10%
SY Rattler	36%	14%	7%	-1%	16%	42%	15%
Average	23%	11%	10%	2%	8%	24%	13%
La Trobe Untreated (t/ha)	4.55	4.53	4.08	3.29	2.79	4.30	3.92
p-value	Variety	<.001	0.003	<.001	<0.001	<.001	<.001
	Control	<.001	<.001	<.001	0.48	<.001	<.001
	Var.Control	<.001	<.001	0.136	0.058	0.679	<.001
Lsd (0.05)	Variety	4.0%	4.6%	2.9%	6.2%	5.4%	2.8%
	Control	2.0%	2.7%	4.4%	6.6%	3.3%	5.5%
	Var.Control	5.7%	5.4%	6.3%	9.5%	9.0%	7.6%
%cv	2.2	2.3	2.1	7.2	8.9	6.7	

However when severity of STNB is considered, the relationship with grain yield response was relatively strong for some varieties (SY Rattler $R^2=0.94$, Hindmarsh $R^2=0.70$, Rosalind $R^2=0.72$, Fathom $R^2=0.72$, Spartacus CL $R^2=0.72$, and Dash $R^2=0.58$), less predictable for others (Granger $R^2=0.42$ and Scope $R^2=0.33$) while La Trobe ($R^2=0.00$) and Compass ($R^2=-0.50$) responses appeared to have no sensible relationship with leaf infection levels (see Figure 2 for some of these relationships). Hindmarsh, Rosalind and Scope showed the highest rates of yield response as STNB severity increased. Most varieties (Hindmarsh, Rosalind, Spartacus CL, Granger and Scope) had significant yield responses starting from when percent leaf area affected on the top three leaves was between 5-10%, but the rate of grain yield response (or yield penalty) differed as %LAA increased from 5%. Fathom was least likely to have %LAA above 10%.

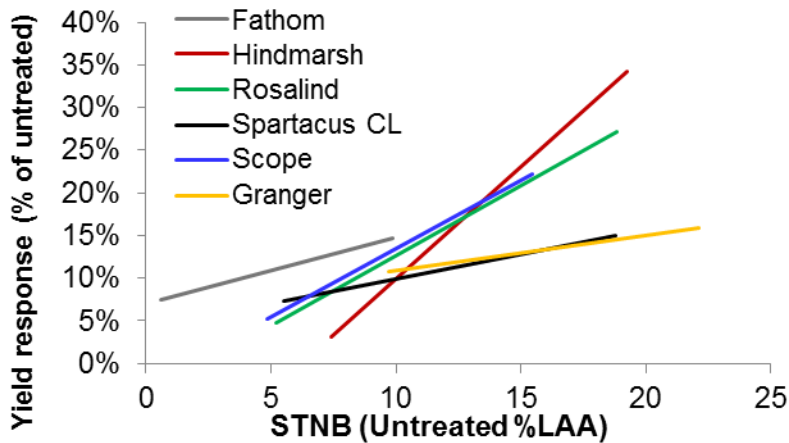


Figure 2. Relationship between STNB severity and grain yield response for six varieties from five responsive sites.

It is possible that the yield responses at Cunderdin were underestimated as levels of STNB in the Controlled plots ranged from 7 to 14% LAA (Table 3). In any case, the yield penalties observed at Cunderdin place it amongst the highest published in Australia (e.g. McLean et al, 2017; Jayasena et al, 2007) and reflect the significance of controlling this disease in the high and medium rainfall zones of WA, particularly in the central region where disease pressure is often very high.

STNB impacts on straw strength and head loss

At Wittenoom Hills, straw strength and head loss were assessed in 2016 and 2017 and demonstrated that disease control can reduce lodging and grain losses, although both traits appeared to be independent of disease resistance ratings. Head losses were pronounced in Hindmarsh, Scope and SY Rattler in 2017 (Figure 3) with some plots shedding over 1t/ha. Losses in Scope were not improved with fungicide application but reductions were evident in Fathom, Hindmarsh, Spartacus and SY Rattler. In general, lodging from weak straw was not severe but was still significantly improved by disease control in both years in SY Rattler, Hindmarsh and Compass (both rated Fair for straw strength), in neither year in Scope (also rated Fair) and in other varieties in one year or the other (Table 5).

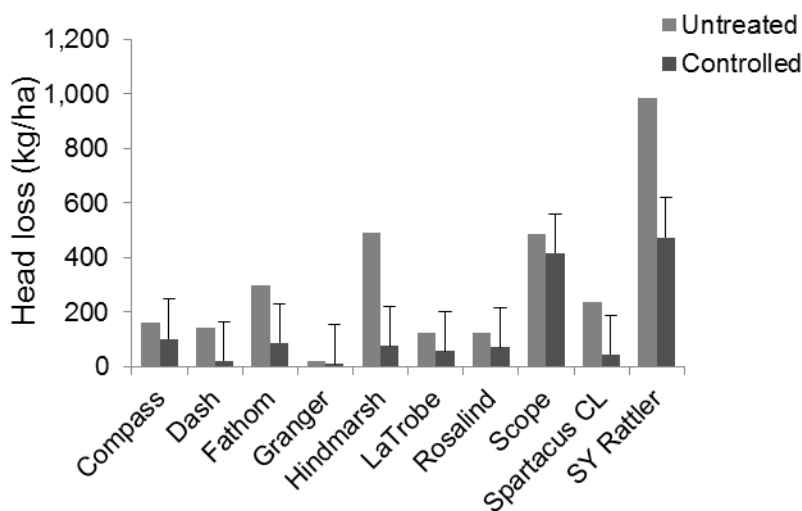


Figure 3. Head loss (kg/ha) for varieties where STNB was Untreated or Controlled. Error bar is the Lsd (0.05) = 144kg.

Table 5. Lodging (0-9 where 9=90°vertical) for varieties at Wittenoom Hills where STNB was Untreated or Controlled. Asterisks indicate varieties where lodging significantly improved.

Variety	Lodging (0-9)			
	2016		2017	
	Untreated	Controlled	Untreated	Controlled
Compass	6.0	6.5*	6.0	6.7*
Dash	6.0	6.3	5.7	6.3*
Fathom	6.3	6.6	6.0	6.8*
Granger	6.3	7.2*	7.7	7.3
Hindmarsh	6.8	7.3*	6.0	6.9*
LaTrobe	6.9	7.4*	6.3	6.8
Rosalind	6.2	6.9*	6.2	6.4
Scope	6.1	6.4	6.3	6.7
Spartacus CL	7.3	7.7	5.7	7.2*
SY Rattler	6.2	6.8*	5.7	6.5*
Average	6.4	6.9	6.1	6.8
p-value	Variety	<.001		<.001
	Control	0.012		<.001
	Var.Control	n.s		<.001
Lsd (0.05)	Variety	0.39		0.35
	Control	0.34		0.22
	Var.Control	-		0.50
cv%		1.7		1.7

* Asterisks (*) indicate varieties where lodging significantly improved

Grain quality

Controlling STNB resulted in a significant improvement in some grain quality measures, particularly screenings, although it had no effect on grain protein (data not shown). In all trials grain screenings decreased when STNB was controlled (Table 6), even when there was no change in grain yield (Nukarni, 2015). Reduction of screenings from disease control without an increase in grain yield is not unusual; Hills et al (2016) found that it occurred in five of 23 STNB fungicide control trials over the last 16 years. Screenings responses varied across varieties and Scope which has a narrow grain shape, responded at all sites. Increases in grain weight were associated with decreased screenings (data not shown).

Table 6. Change in screenings (%<2.5mm) in WA malt/food varieties when STNB is controlled.

Variety	Wittenoom Hills			Nukarni		Cunderdin
	2015 [#]	2016	2017	2015	2016	2017
Compass	-4	-2*	-3*	-6*	-3*	-4
Granger	-9*	-3*	-1*	-11*	-5*	-6*
Hindmarsh	-26*	-7*	-4*	1	-3*	-13*
LaTrobe	-17*	-5*	-3*	-1	-2*	-7*
Scope	-12*	-6*	-1*	-6*	-8*	-13*
Spartacus CL	0	-4*	-2*	0	-2*	-7*
La Trobe Untreated (%)	35%	11%	6%	19%	12%	14%
p-value	Variety	0.002	<.001	<.001	<.001	<.001
	Control	<.001	<.001	<.001	<.001	<.001
	Var.Control	<.001	<.001	<.001	0.089	<.001
Lsd (0.05)	Variety	3.3	1.4	0.2	7.0	2.2
	Control	5.5	1.6	0.2	3.5	1.1
	Var.Control	6.2	2.4	0.3	3.5	5.1
cv%		6.7	3.6	8.2	7.2	14.0

* An asterisk (*) indicates a significant decrease in percentage screenings by disease control

shaded cells are those changes that decreased screenings from above to below the 20% limit for Malt/Food 1 receivals.

Disease control increased hectolitre weights by around 0.9 kg/hL, although all already met the Malt1/Food1 specifications in all years except at Nukarni in 2015 (data not shown).

Grain brightness was good at all sites in all years with disease control increasing this at Wittenoom Hills in the southern region (Table 7) although all met the threshold for Malt1/Food1 deliveries.

Table 7. The change in grain brightness (NIR L*) in WA malt/food or feed barley varieties at Wittenoom Hills when STNB is controlled.

Variety		Grain brightness (NIR L*)		
		2015	2016	2017
Compass		2*	1*	2*
Granger		2*	2*	2*
Hindmarsh		1*	0	3*
LaTrobe		1*	0	3*
Scope		1*	0	2*
Spartacus CL		0	1*	4*
La Trobe Untreated		62	59	61
p-value	Variety	<.001	<.001	<.001
	Control	0.002	<.001	<.001
	Var.Control	0.011	<.001	<.001
Lsd (0.05)	Variety	0.3	0.3	0.3
	Control	0.6	0.5	0.5
	Var.Control	0.6	0.7	0.7
%cv		0.2	0.3	0.4

* Asterisks indicate significant increases with disease control

Conclusion

Differences were evident between varieties in STNB severity and these differences were generally related to variety resistance rankings. Fungicide control of STNB increased the grain yield of all the barley cultivars in these trials. Grain quality, particularly screenings and grain brightness, were also improved with STNB control. Variety yield response to disease control usually started when leaf infection severity reached 5-10% (average of the Flag to Flag-2). As disease severity increased, the rate of yield response varied markedly between varieties; Hindmarsh, Scope and Rosalind had the highest yield losses as STNB levels increased, Granger and Spartacus CL were moderately responsive while other varieties such as La Trobe and Compass had significant but more unpredictable levels of response to STNB levels.

The best way for growers to limit impact of STNB on crop yield is to reduce disease severity by utilisation of variety resistance or reducing disease inoculum (stubble management, crop rotation). However, when disease severity is greater than 5-10% leaf area affected on Flag to Flag-2 and spring conditions favour disease development, most varieties show yield and grain quality responses to fungicide application.

Key words

Barley, variety, yield, spot-type net blotch, spot-form net blotch, *Pyrenophora teres* f. *maculata*

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