South African Barley Breeding Institute

SABBI

EFFECTS OF FUNGICIDE ON GRAIN YIELD AND QUALITY OF BARLEY

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ABSTRACT

The effect of fungicides and their combination on the yield of barley was investigated during this study. Various fungicide treatments (No fungicide, Artea, Abacus and Strobilurin A) and combinations of these were applied at different growth stages. It is important to note that the net blotch incidence was low through out the trial. Furthermore, the results presented and discussed here are from only one location during a two year period. The results may not be representative of the whole dry land barley producing area. RCB analyses indicated that the double strobilurin applications or a triazole followed by a strobilurin gave the best results. Treatment 2 (double strobilurin) and Treatment 7 (triazole/strobilurin) showed the highest income difference deviation, 13.6% and 10.8% respectively from the control. Treatment 2 provided an additional R1778 per hectare in 2007 and Treatment 7 an additional R2402 per hectare in 2008. Erica (12%) followed by Nemesia (10%) and S7 (10%) showed the highest average yield difference compared to the standard SSG 564.

INTRODUCTION

The application of fungicides is an important way to increase cereal crop yield. However the results produced by different types of fungicide and different application doses depend on the weather, soil and management conditions. Some authors have stated that fungicide application increased yield in most situations even without observable disease problems. Currently two different fungicide groups (DMIs, the triazoles and QoI, the strobilurins) are mainly used for barley production. DMIs (i.e. Artea) are also known as sterol biosynthesis inhibitors or ergosterol biosynthesis inhibitors. DMIs are a subgroup of SBIs that are chemically diverse, but all have a common mode of action in disrupting sterol synthesis at a single biochemical site. Since their introduction, a large number of new DMI active ingredients have become available. They are highly effective against powdery mildews, rusts and smuts, as well as a wide range of other ascomycete and imperfect fungi (Table 1). They show varying degrees of systemic activity. There is potential cross-resistance amongst all the active ingredients within the DMI fungicides.

QoI (i.e. Abacus) fungicides are synthetic derivatives of naturally occurring strobilurin compounds and are active against a broad spectrum of fungi (Table 1). They have a site-specific mode of action that inhibits fungal respiration at the Quinone "outside" (Qo) binding site of the cytochrome bc1 complex. The site-specific mode of action means they are at risk from the development of resistance in the target plant pathogens. QoI's are not cross resistant with other fungicide groups, but there is cross-resistance among all the active ingredients within the group. The range of pathogens against which the various QoI compounds are effective differs with the compound. The objective of this work was to clarify the effect of different fungicide treatments (QoI – fungicides, DMI-fungicides) and combinations of these for the various experimental and commercial varieties in the Rûens.

Table1: Pathogens targeted by DMI and QoI fungicides

Pathogen	Disease	DMI	QoI
Blumeria graminis	Powdery mildew	√	√
Cochliobolus sativus	Spot blotch		√
Leptosphaeria nodorum	Glume blotch	√	
Mycosphaerella graminicola	Speckled leaf blotch	√	
Oculimacula spp.	Eye spot	√	
Puccinia spp.	Leaf rust	√	√
Pyrenophora teres	Net blotch	√	√
Species of Alternaria,Cladosporium, Stemphylium and Fusarium	Head disease complex		√
Ramularia collo-cygni	Leaf and awn spot	√	√
Rhynchosporium secalis	Scald	√	√
Ustilago spp.	Covered/Loose smut	√	

Material and methods

The field experiment was conducted during the 2007 and 2008 crop year. The experimental design was a triple-replicate split-plot design with the fungicide treatments as the main plots and the six cultivars as the subplot (6m x 1m). The trial was planted on SABBI's farm with a plot planter at a seed density of 80kg/ha. Standard maintenance for weed and insect control were done. The varieties investigated over the two-year period were SSG 564, SabbiErica, SabbiNemesia and S5. Additional cultivars SSG 506, S02-11 (2007) and S6, S7 (2008) were also investigated.

Treatments 1-5 (2007) and Treatments 1,4,5,6 and 7 (2008) were applied during the trial period. A summary of the treatments are given in table 2 below. It is important to note that the strobilurin based fungicides are mixtures containing active ingredients from both the QoI and DMI group. Strobilurin A is an experimental fungicide with a different active ingredient than Artea, and is currently in the process of being registered.

Table 2: Summary of treatments

	Spray 1 6 weeks after plant	Spray 2 12 weeks after plant	Spray 3 3weeks after T2
Treatment 1	No Fungicide	-	-
Treatment 2	Strobilurin A (800ml/ha)	Strobilurin A (800ml/ha)	-
Treatment 3	Abacus (1000 ml/ha)	Abacus (1000 ml/ha)	-
Treatment 4	Artea (500ml/ha)	Strobilurin A (800ml/ha)	-
Treatment 5	Strobilurin A (800ml/ha)	Artea (500ml/ha)	-
Treatment 6	Artea (500ml/ha)	Strobilurin A (800ml/ha)	Artea (500ml/ha)
Treatment 7	Artea (500ml/ha)	Abacus (800ml/ha)	-

Readings for the development of net blotch (*Pyrenophora teres*) and scald (*Rhynchosporium secalis)* were taken on each plot and the trial was harvested according to the normal protocol. The yield, plumpness and kernel nitrogen were determined.
The total income per ha was calculated on a base price of R1755 per ton for 2007 and R2810 per ton for 2008. The quality premium was based on differences in plumpness and nitrogen. The income difference between treatments was calculated by subtracting only the cost of the treatments from the total income. For this exercise, application costs were ignored.

RESULTS

Table 3: Data of agronomic characteristics of all varieties per treatment

	Yield (kg/ha)		Plumpness		Kernel nitrogen	
Treatment	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
No fungicide	5814cd	7654b	81.2b	92.9b	1.78b	1.70b
Strobilurin A/Strobilurin A	6735a		88.7a	-	1.78b	-
Abacus/Abacus	6158b		90.9a	-	1.78b	-
Artea/Strobilurin A	6021bc	8337a	90.3a	92.5b	1.82ab	1.77a
Strobilurin A/ Artea	5682d	8125a	89.6a	93.0b	1.87a	1.75a
Artea/Strobilurin A/Artea	-	8425a	-	92.5b	-	1.75a
Artea/Abacus	-	8376a	-	94.5a	-	1.73a
CV	9.0	8.2	7.6	2.4	5.3	4.1
LSD ($T_{0.10}$)	236	292	2.9	1.0	0.04	0.03
LSD ($T_{0.05}$)	304	376	3.7	1.3	0.05	0.04

Different letters after the data implies that there is a significant difference between the two values at a 95% confidence level.

Table 4: Comparison of brute income per hectare minus cost for all varieties per treatment

	Total Income R/ha		Treatment cost R/ha		Income Difference		% Deviation	
Treatment	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
Treatment 1	10,695	22,250	-	-	10,695	22,250		
Treatment 2	12,473	-	326	-	12,146	-	13.6	
Treatment 3	11,426	-	408	-	11,018	-	3.0	
Treatment 4	11,172	24,058	248	352	10,924	23,706	2.1	6.5
Treatment 5	10,354	23,743	248	352	10,106	23,391	-5.5	5.1
Treatment 6	-	24,625	-	472	-	24,153		8.6
Treatment 7	-	25,062	-	410	-	24,652		10.8

Percentage deviation calculated as [(treated-untreated)\untreated] X 100

Figure 1: Comparison of percentage deviation of income difference R/ha calculated from control over treatments

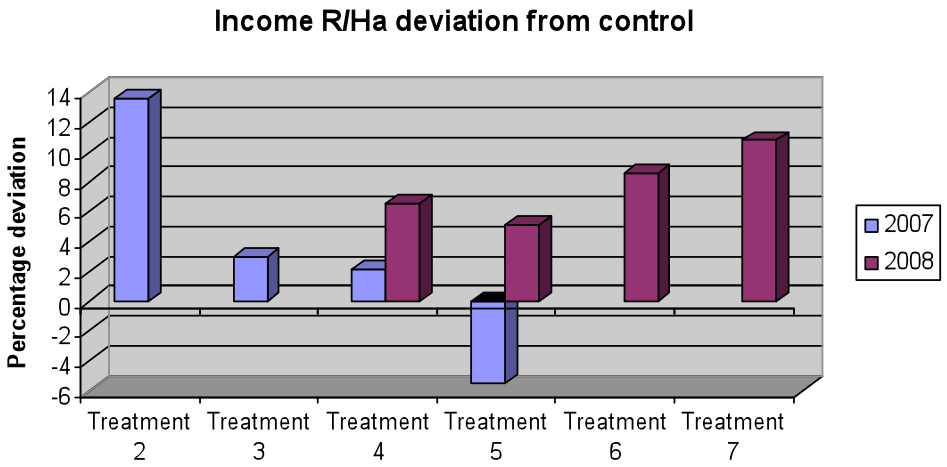


Table 5: Yield (kg/ha) of all treatments per variety, 2007

	SSG 564	SSG 506	S02-11	Erica	Nemesia	S5
T1	5369b	5715b	5021c	5892b	5458c	5720c
T2	6443a	6489a	6184a	7186a	6752a	6788a
T3	5668ab	5988ab	5676b	7233a	6871a	6857a
T4	5523b	5679b	5603b	6418b	6383ab	6286b
T5	5788ab	5931ab	5513b	6215b	5862bc	5956bc
CV	9.2	6.3	4.5	6.0	9.2	3.9
LSD ($T_{0.10}$)	603	434	293	454	659	288
LSD ($T_{0.05}$)	803	582	393	608	878	386

Different letters after the data implies that there is a significant difference between the two values at a 95% confidence level.

Table 6: Yield (kg/ha) of all treatments per variety, 2008

	SSG 564	Erica	Nemesia	S5	S6	S7
T1	7251b	7166b	7856b	7542b	8109bc	8075b
T4	7000b	8619a	8644ab	7987b	9020a	7862b
T5	7371b	8564a	8444ab	7977b	7480c	8609ab
T6	8323a	8493a	8695a	7777b	7964bc	9042a
T7	8269a	8746a	8924a	8897a	8316ab	8481ab
CV	7.5	7.5	7.5	7.5	7.5	7.5
LSD ($T_{0.10}$)	499	499	499	499	499	499
LSD ($T_{0.05}$)	834	834	834	834	834	834

Different letters after the data implies that there is a significant difference between the two values at a 95% confidence level.

Table 7: Summary of effect of treatments on yield

	SSG 564	SSG 506	S02-11	Erica	Nemesia	S5	S6	S7
T2_2007	+	+	+	+	+	+		
T3_2007	ns	ns	+	+	+	+		
T4_2007	ns	ns	+	ns	+	+		
T4_2008	ns			+	ns	ns	+	ns
T5_2007	ns	ns	+	+	ns	ns		
T5_2008	ns			ns	ns	ns	ns	ns
T6_2008	+			+	+	ns	ns	+
T7_2008	+			+	+	+	ns	ns

+ indicates yield is significantly higher than the control at a 95% confidence level, ns indicates no significant difference from the control.

Table 8: Percentage plumpness of all treatments per variety 2007

	SSG 564	SSG 506	S02-11	Erica	Nemesia	S5
T1	85.1b	97.4a	86.6c	72.2 b	63.7b	82.1 b
T2	90ab	91.4a	89.4bc	85.8a	81.4a	92.3a
T3	90.8a	96.2a	94.5a	82.9a	87.5a	95.0a
T4	93.7a	97.2a	91.7ab	84.3a	82.0a	93.8a
T5	90.3a	98.8a	89.6ab c	80.9a	84.2a	92.8a
CV	3.6	5.1	3.6	6.8	7.3	4.4
LSD ($T_{0.10}$)	3.7	5.7	3.7	6.3	6.6	4.6
LSD ($T_{0.05}$)	4.9	7.7	5.0	8.4	8.8	6.2

Different letters after the data implies that there is a significant difference between the two values at a 95% confidence level.

Table 9: Percentage plumpness of all treatments per variety 2008

	SSG 564	Erica	Nemesia	S5	S6	S7
T1	87.9b	89b	93.4a	93.7a	97.1a	96.1a
T4	86.6b	90.2ab	93.3a	94.5a	94.5b	95.7a
T5	86.5b	89.5b	95.1a	93.9a	97.1ab	96.0a
T6	86.0b	91.1ab	95.4a	95.3a	96.2ab	91.0b
T7	91.2a	92.9a	95.3a	93.5a	98.0a	95.0a
CV	2.1	2.1	2.1	2.1	2.1	2.1
LSD ($T_{0.10}$)	2.1	2.1	2.1	2.1	2.1	2.1
LSD ($T_{0.05}$)	2.7	2.7	2.7	2.7	2.7	2.7

Different letters after the data implies that there is a significant difference between the two values at 95% confidence level, ns indicates no significant difference from the control.

Table 10: Summary of effect of treatments on Percentage plumpness

	SSG 564	SSG 506	S02-11	Erica	Nemesia	S5	S6	S7
T2_2007	ns	ns	ns	+	+	+		
T3_2007	+	ns	+	+	+	+		
T4_2007	+	ns	+	+	+	+		
T4_2008	ns			ns	ns	ns	ns	ns
T5_2007	+	ns	ns	+	+	+		
T5_2008	ns			ns	ns	ns	ns	ns
T6_2008	ns			ns	ns	ns	-	-
T7_2008	+			+	ns	ns	ns	ns

+ indicates yield is significantly higher, and – significantly lower than the control at a 95% confidence level, ns indicates no significant difference from the control.

Table 11: Kernel nitrogen of all treatments per variety, 2007

	SSG 564	SSG 506	S02-11	Erica	Nemesia	S5
T1	1.80a	1.83a	1.80a	1.85a	1.91a	1.80ab
T2	1.79a	1.89a	1.80a	1.85a	1.91a	1.84a
T3	1.71a	1.78a	1.85a	1.84a	1.85a	1.77ab
T4	1.66a	1.88a	1.85a	1.80a	1.87a	1.71b
T5	1.71a	1.86a	1.74a	1.80a	1.77a	1.70b
CV	5.7	3.9	7.5	3.9	7.8	3.9
LSD ($T_{0.10}$)	0.11	0.08	0.15	0.08	0.16	0.08
LSD ($T_{0.05}$)	0.15	0.11	0.20	0.11	0.22	0.11

Different letters after the data implies that there is a significant difference between the two values at a 95% confidence level.

Table 12: Kernel nitrogen of all treatments per variety, 2008

	SSG 564	Erica	Nemesia	S5	S6	S7
T1	1.67b	1.73b	1.79a	1.71a	1.67b	1.63a
T4	1.74ab	1.88a	1.80a	1.77a	1.80a	1.62a
T5	1.76ab	1.85a	1.72a	1.77a	1.69b	1.71a
T6	1.78a	1.85a	1.76a	1.70a	1.74ab	1.68a
T7	1.78a	1.83a	1.71a	1.73a	1.68b	1.67a
CV	3.8	3.8	3.8	3.8	3.8	3.8
LSD ($T_{0.10}$)	0.07	0.07	0.07	0.07	0.07	0.07
LSD ($T_{0.05}$)	0.09	0.09	0.09	0.09	0.09	0.09

Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Table 13: Summary of effect of treatments on Kernel nitrogen

	SSG 564	SSG 506	S02-11	Erica	Nemesia	S5	S6	S7
T2_2007	ns	ns	ns	ns	ns	ns		
T3_2007	ns	ns	ns	ns	ns	ns		
T4_2007	ns	ns	ns	ns	ns	ns		
T4_2008	ns			+	ns	ns	+	ns
T5_2007	ns	ns	ns	ns	ns	ns		
T5_2008	ns			+	ns	ns	ns	ns
T6_2008	+			+	ns	ns	ns	ns
T7_2008	+			+	ns	ns	ns	ns

Figure 2: Percentage deviation in yield from unsprayed control with different treatments for the 2007 season.

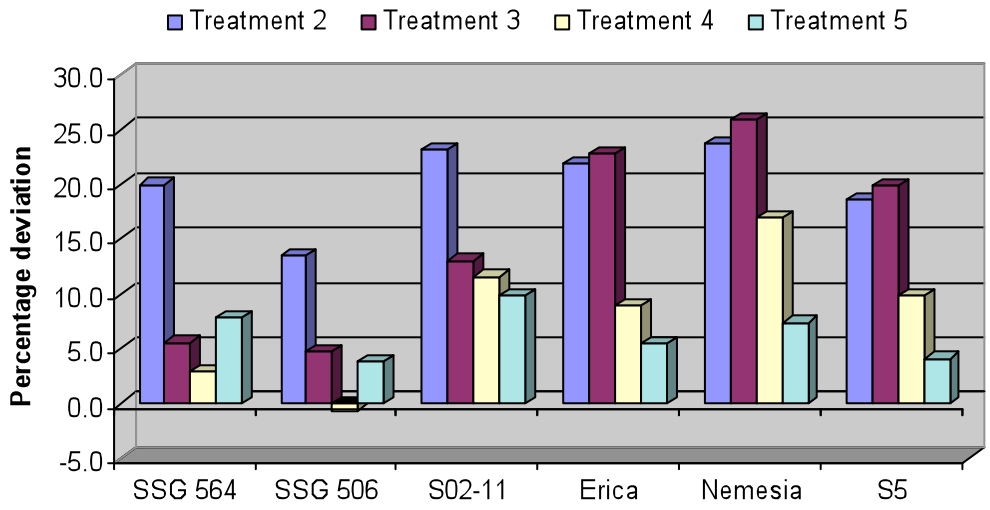


Figure 3: Percentage deviation in yield from unsprayed control with different treatments for the 2008 season.

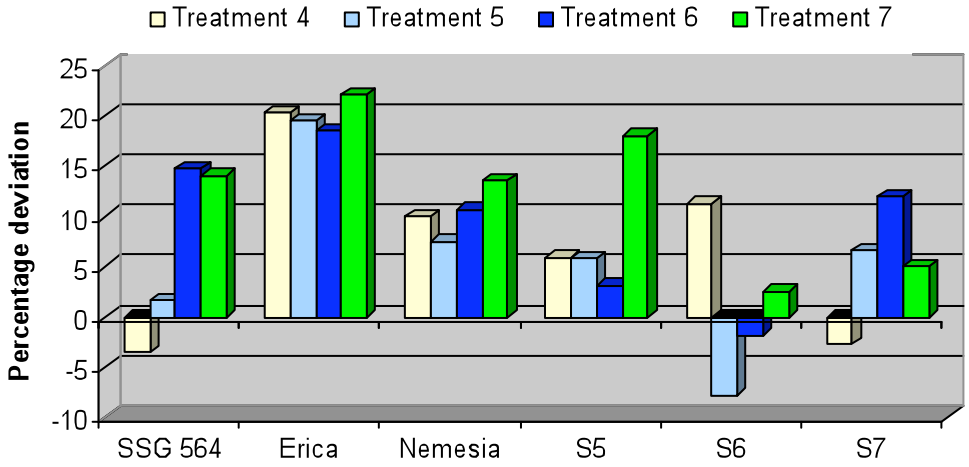
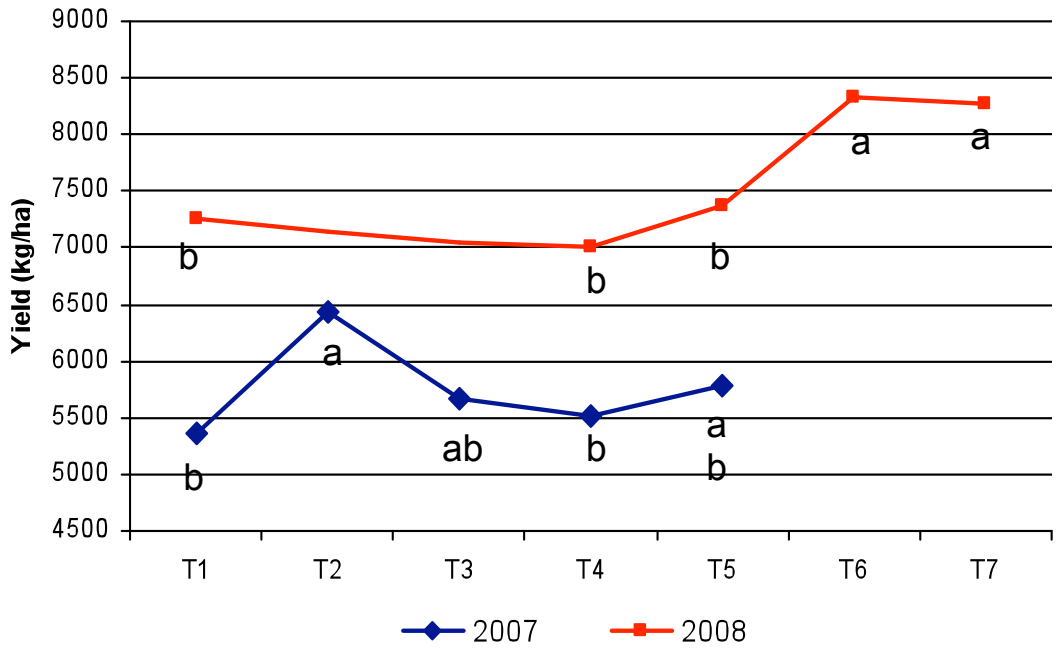
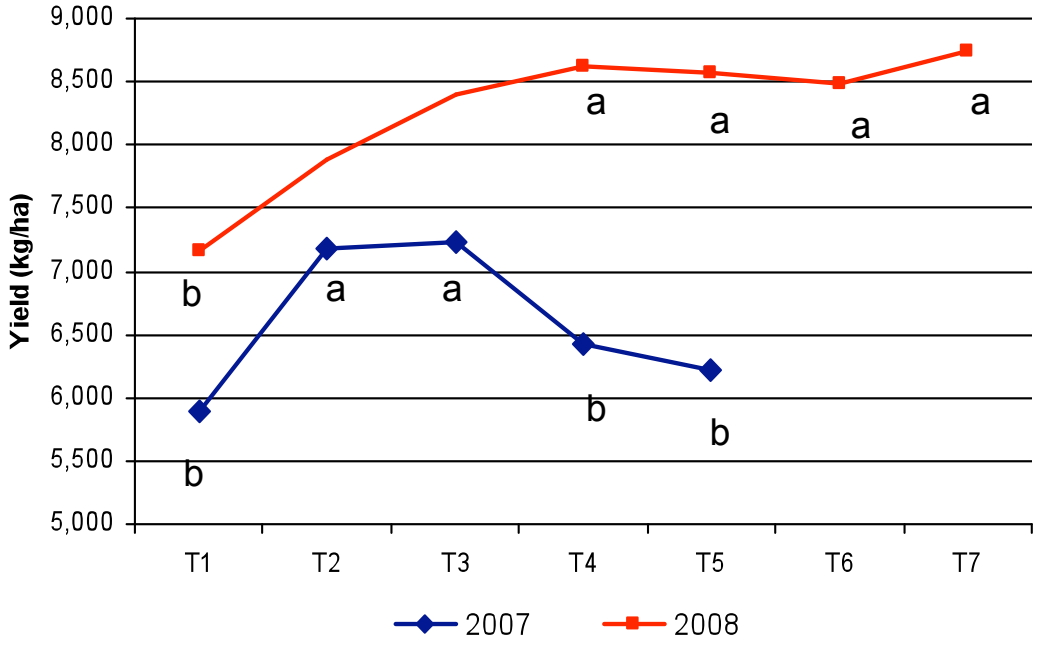


Figure 4: Change in yield (kg/ha) of SSG 564 with different treatments



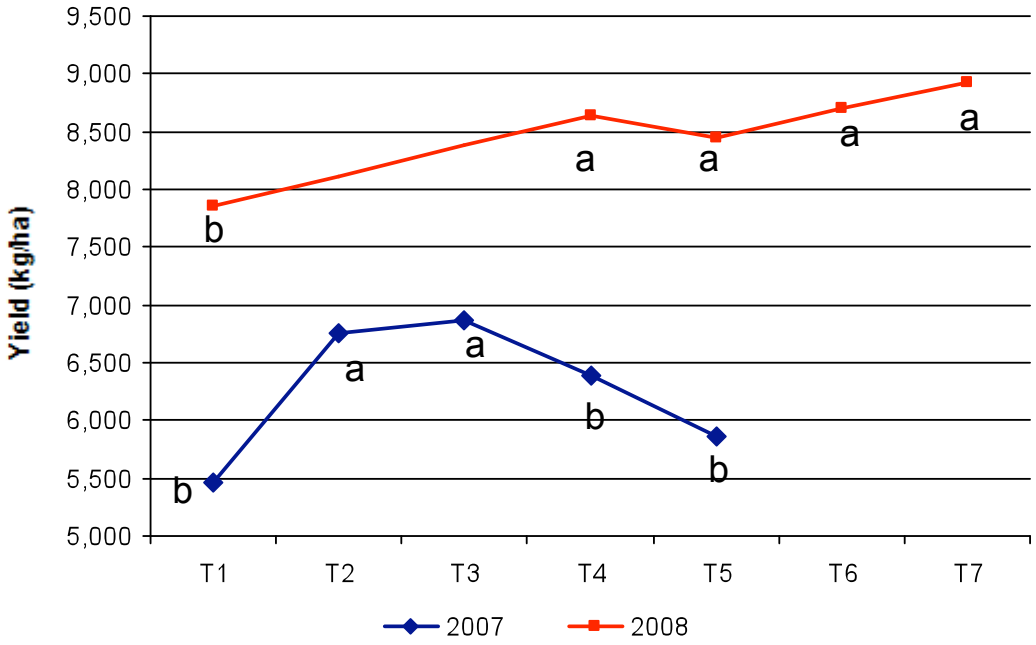
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 5: Change in yield (kg/ha) of Erica with different treatments



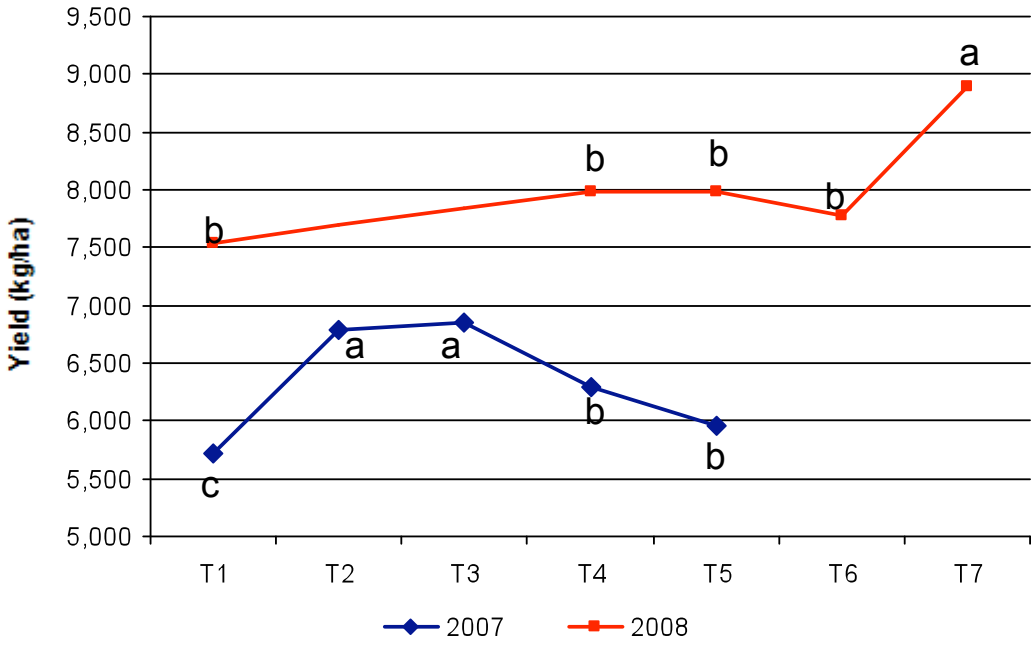
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 6: Change in yield (kg/ha) of Nemesia with different treatments



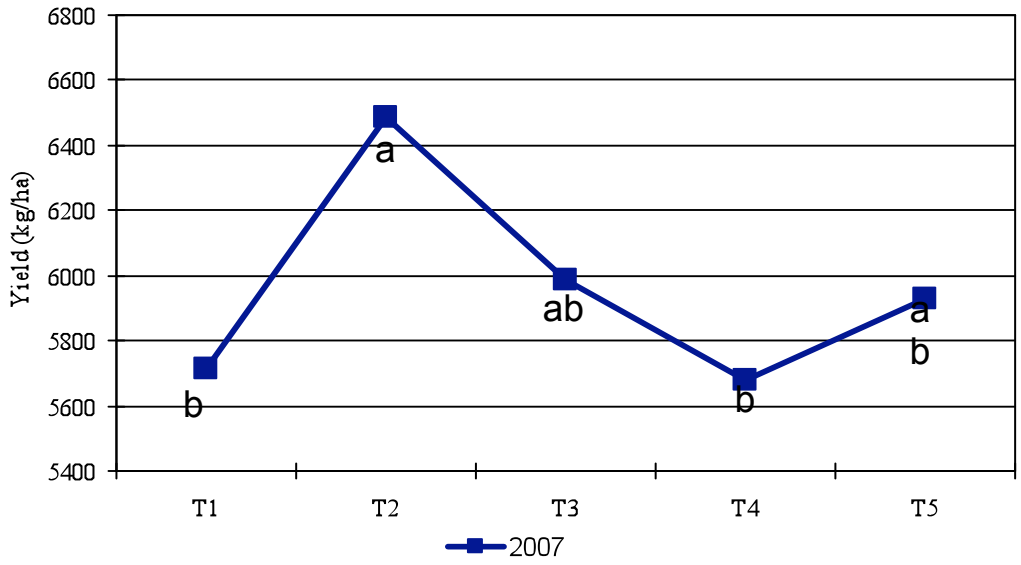
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 7: Change in yield (kg/ha) of S5 with different treatments



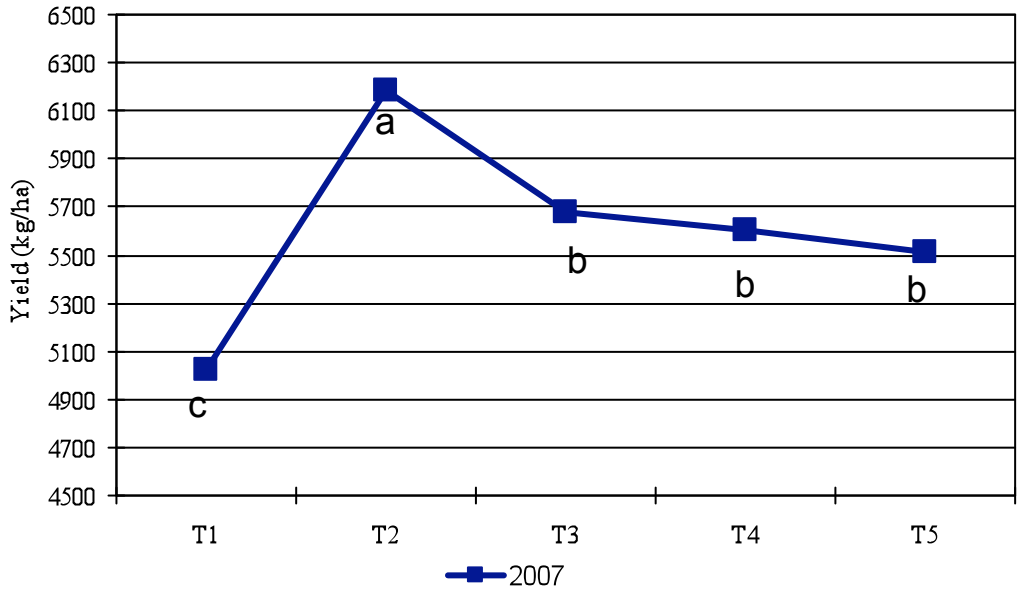
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 8: Change in yield (kg/ha) of SSG 506 with different treatments



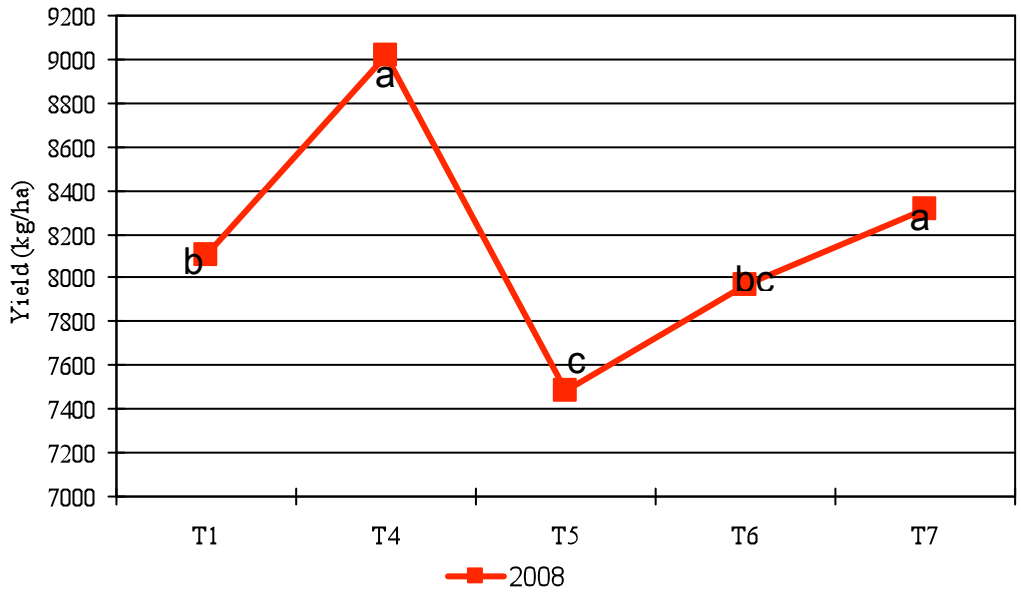
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 9: Change in yield (kg/ha) of S02-11 with different treatments



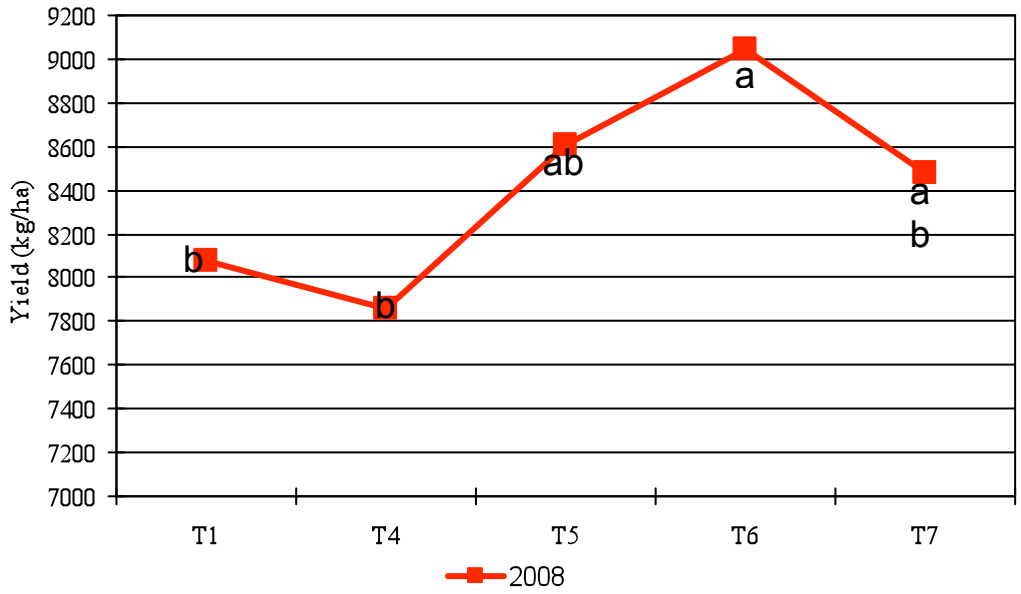
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 10: Change in yield (kg/ha) of S6 with different treatments



Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 11: Change in yield (kg/ha) of S7 with different treatments



Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 12: Deviation of income difference (R/ha) of treatments calculated as a percentage of the control, 2007

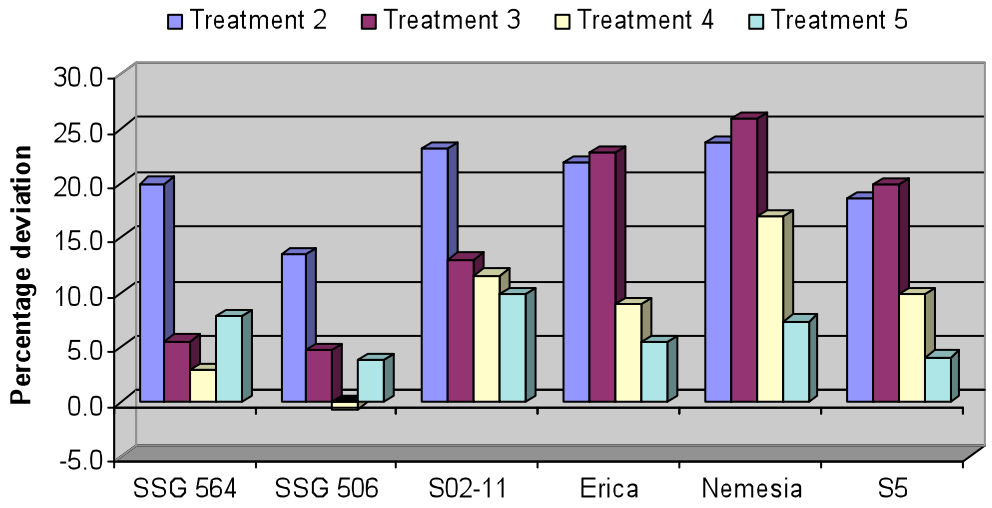


Figure 13: Deviation of income difference (R/ha) of treatments calculated as a percentage of the control, 2008

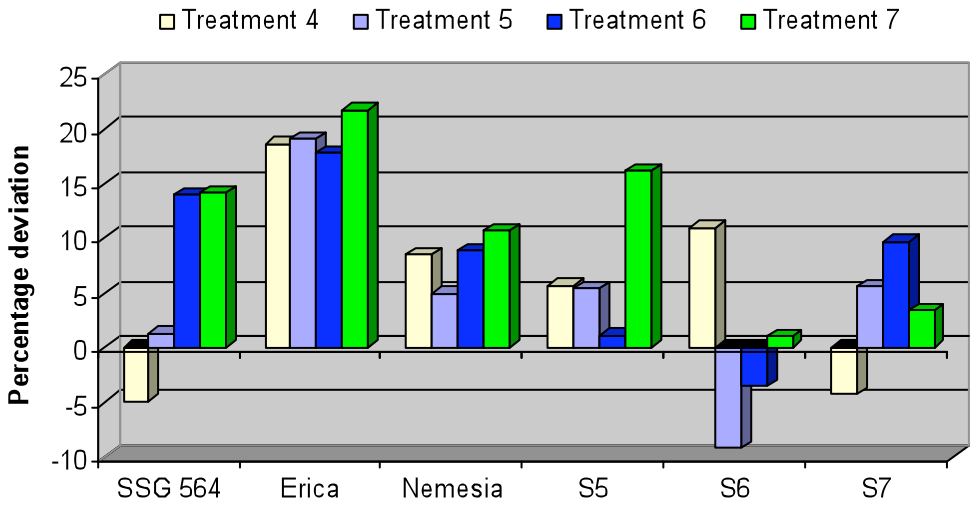


Figure 14: Net blotch readings for varieties with different treatments
(0 = no visible disease; 9 = whole leaf infested) for the 2007 season

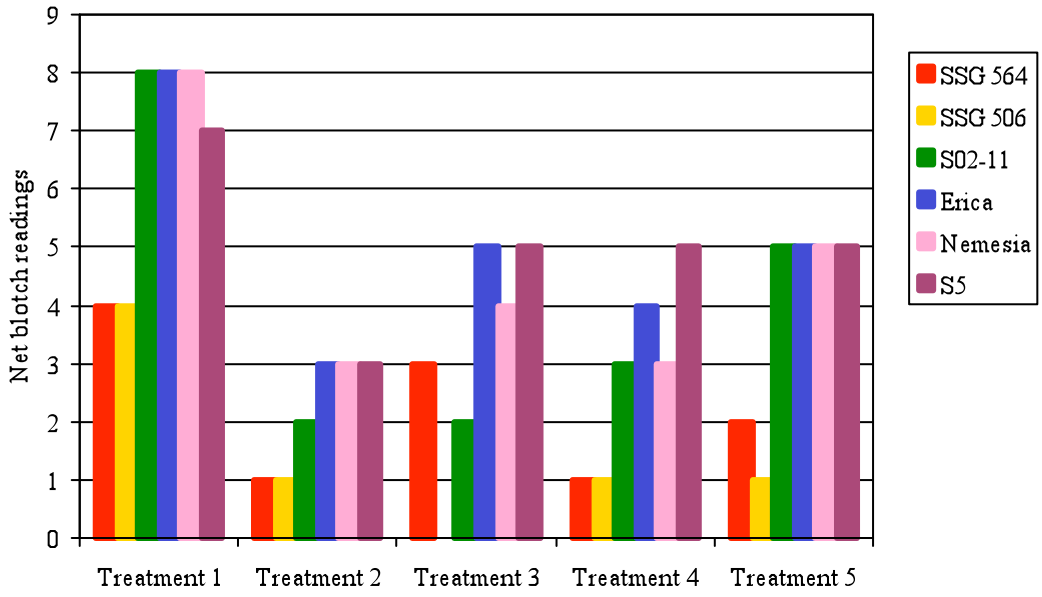


Figure 15: Net blotch readings for varieties with different treatments
(0 = no visible disease; 9 = whole leaf infested) for the 2008 season

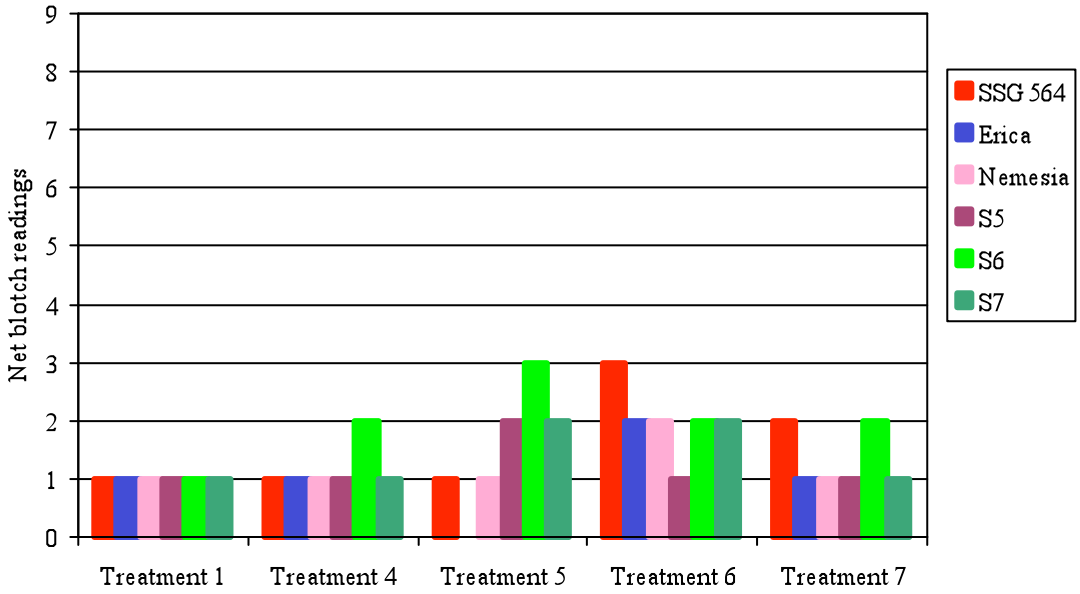


Figure 16: Scald readings for varieties with different treatments for the 2007 season
(0 = no visible disease; 9 = up to the flag leaf)

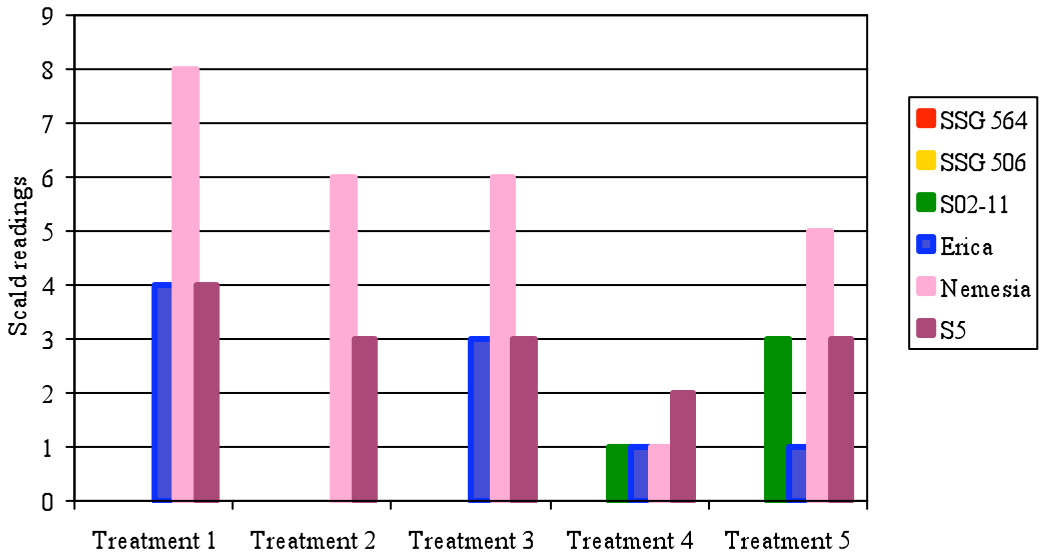
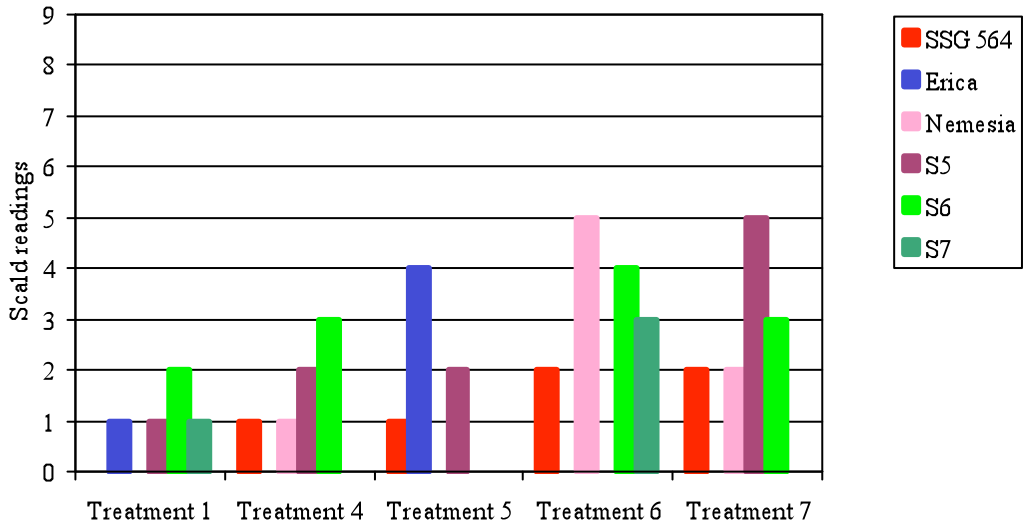


Figure 17: Scald readings for varieties with different treatments for the 2008 season
(0 = no visible disease; 9 = up to the flag leaf)



DISCUSSION

1. It is important to note that the results presented and discussed here, are from only one location during a two year period. The results may not be representative of the whole dry land barley producing area.

2. It is clear from the results presented here that yield response to fungicide treatment is strongly affected by differences between years and varieties.

3. From Figure 14 it is evident that the incidence of net blotch reached high levels at the end of the 2007 growing season. The net blotch incidence was uncharacteristically low during the 2008 growing season. For the first time in years scald also developed, possible due to the low incidence of net blotch. However, the disease development started only at a late stage during both seasons, and the effect was not as severe as expected.

4. The 2007 data shows clearly, that there are differences in the degree of resistance to net blotch between the varieties. SSG 564 and SSG 506 showed good resistance with the other four highly susceptible. During seasons with a low disease pressure (2008), it is difficult to asses cultivar resistance. The low incidence of natural infection makes it difficult to differentiate between resistance and exclusion. Consequently, a low disease reading does not necessarily indicate resistance.

5. The double strobilurin application (Treatments 2 and 3) in the 2007 crop, and all the fungicide treatments in 2008 showed a significant increase in yield over all varieties with split plot analysis.

6. Erica (12%) followed by Nemesia (10%) and S7 (10%) showed the highest average yield difference compared to SSG 564

7. S02-11 (-2.8%) was the only cultivar that showed a lower yield than SSG 564

8. Erica (17%) followed by Nemesia (14%) and S02-11 (14%) showed the highest average yield improvement between sprayed and unsprayed plots.

9. Due to the volatile nature of the percentage plumpness and kernel nitrogen data over years, more data points are needed to draw a conclusion with split plot analysis.

10. RCB analyses indicated that the double strobilurin applications or a triazole followed by a strobilurin gave the best results. However, it is important to note that the efficacy of the various strobilurin-based products on the market differs.

11. The cost of the different treatments varied from R248 to R472.

12. Treatment 2 (double strobilurin) and Treatment 7 (triazole/strobilurin) showed the highest income difference deviation, 13.6% and 10.8% respectively from the control. Treatment 2 provided an additional R1778 per hectare in 2007 and Treatment 7 an additional R2402 per hectare in 2008.

13. It appears that Treatment 2 gave the best control of net blotch on the majority of the varieties, while Treatment 5 seems to be the least effective for net blotch suppression.

14. From Table 7 (as illustrated in Figures 4 and 8) it is evident that the same pattern for variety/fungicide interaction followed with SSG 564 and SSG 506. Although Treatment 2 showed the highest yield, it was not significantly higher than that of treatments 3 and 5.Treatment 6 and 7 showed the highest yield in 2008, and it was significantly higher than that the other treatments.

15. S02-11, Erica, Nemesia and S5 showed a similar pattern for variety/fungicide interaction. Treatments 2 , 3 , 6 (with the exception of S5) and 7 showed statistically higher yields than the control.

16. S6 showed only a statistically higher yield with Treatment 4.

17. S7 showed a statistically higher yield with Treatment 6.