South African Barley Breeding Institute

SABBI

EFFECTS OF FUNGICIDE ON GRAIN YIELD AND QUALITY OF BARLEY GROWN IN THE RÛENS

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Abstract

The effect of fungicides and their combination on the performance of SABBI's barley varieties 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. The results presented and discussed here are from only one location during a three year period. The results may not be representative of the whole dry land barley producing area. During 2007, net blotch only established late in the season which explains why the treatments with a second application of strobilurin performed better. In 2008 the disease pressure have was extremely low, and the results confirmed the beneficial effects of fungicides in the absence of fungal diseases. Leaf blotch was the predominant fungal disease in 2009 and all treatments only delivered positive results.

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 in 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 Ascomycetes 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 Southern Cape.

Table1: Pathogens targeted by DMI and Qol fungicides

Pathogen	**Disease**	**DMI**	**Qol**
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, 2008 and 2009 crop years. The experimental design was a triple-replicate split-plot design with the fungicide treatments as the main plots and six varieties 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 three-year period were SSG 564, SabbiErica, SabbiNemesia and S5. Additional varieties, namely SSG 506, S02-11 (2007) and S6, S7 (2008 and 2009) were also investigated.

Treatments 1-5 (2007), Treatments 1,4,5,6 and 7 (2008), and Treatments 1,2,4,5 and 6 (2009) 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 Qol and DMI group. Strobilurin A is an experimental fungicide with a different active ingredient than Abacus, 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)	-
Treatment 8	Unix+ Tilt (500g + 400ml/ha)	Artea (500ml/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, R2810 per ton for 2008 and R2105 for 2009. 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**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
1	5814cd	7654b	4407b	81.2b	92.9b	92.4c	1.78b	1.70b	1.62
2	6735a	-	5686a	88.7a	-	94.5b	1.78b	-	1.58
3	6158b	-	-	90.9a	-		1.78b	-	-
4	6021bc	8337a	5556a	90.3a	92.5b	94.9ab	1.82ab	1.77a	1.62
5	5682d	8125a	5951a	89.6a	93.0b	94.4b	1.87a	1.75a	1.66
6	-	8425a	5846a	-	92.5b	95.8a	-	1.75a	1.67
7	-	8376a	-	-	94.5a		-	1.73a	
CV	9.0	8.2	16.7	7.6	2.4	2.2	5.3	4.1	6.9
LSD ($T_{0.10}$)	236	292	399	2.9	1.0	0.9	0.04	0.03	0.05
LSD ($T_{0.05}$)	304	376	515	3.7	1.3	1.2	0.05	0.04	0.06

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 bruto income per hectare minus cost for all varieties per treatment

	Total Income R/ha			Treatment cost R/ha			Income Difference			% Deviation		
Tmt.	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
1	10,695	22,250	9,176	-	-	-	10,695	22,250	9,176			
2	12,473	-	12401	326	-	365	12,146	-	12,036	13.6		35.2
3	11,426	-	-	408	-	-	11,018	-	-	3		
4	11,172	24,058	11,458	248	352	302	10,924	23,706	11,155	2.1	6.5	24.9
5	10,354	23,743	13,706	248	352	302	10,106	23,391	13,403	-5.5	5.1	49.4
6	-	24,625	12,901	-	472	422	-	24,153	12479		8.6	40.6
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.

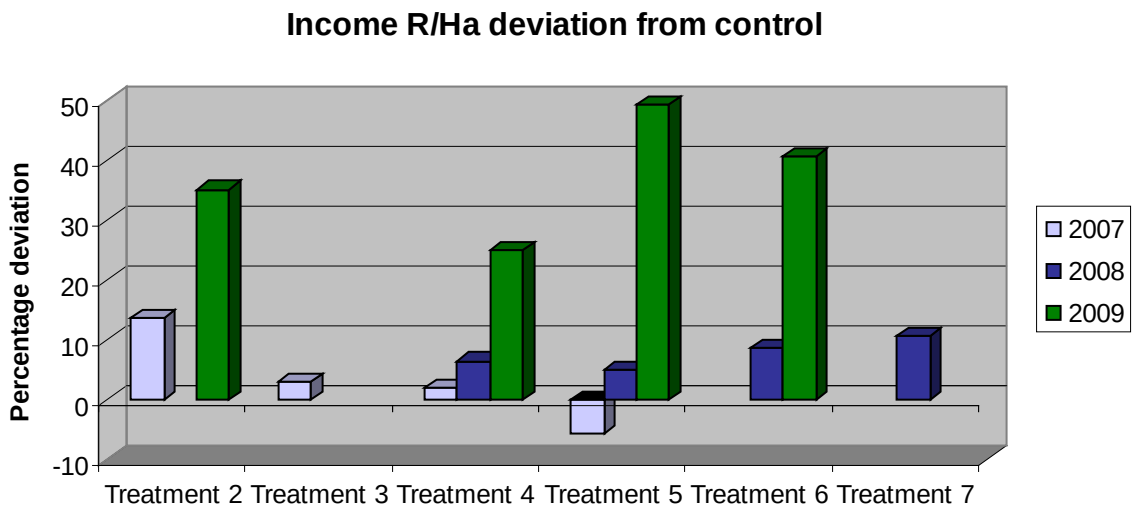


Table 5: Yield (kg/ha) of all treatments per variety, 2007

	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: Yield (kg/ha) of all treatments per variety, 2009

	SSG 564	Erica	Nemesia	S5	S6	S7
T1	3826d	4380c	3822c	3643c	4588b	5156c
T2	5006bc	6143b	5792ab	5185b	6183a	6020b
T4	4639c	5582b	5583b	5061b	4659b	6279ab
T5	5467ab	7068a	6315a	5980a	6081a	6752a
T6	6035a	5658b	5855ab	5115b	5965a	6839a
CV	8.8	8.8	8.8	8.8	8.8	8.8
LSD ($T_{0.10}$)	511	511	511	511	511	511
LSD ($T_{0.05}$)	658	658	658	658	658	658

Table 8: Summary of effect of treatments on yield

	SSG 564	SSG 506	S02-11	Erica	Nemesia	S5	S6	S7
T2_2007	+	+	+	+	+	+		
T2_2009	+			+	+	+	+	+
T3_2007	ns	ns	+	+	+	+		
T4_2007	ns	ns	+	ns	+	+		
T4_2008	ns			+	ns	ns	+	ns
T4_2009	+			+	+	+	ns	+
T5_2007	ns	ns	+	+	ns	ns		
T5_2008	ns			ns	ns	ns	ns	ns
T5-2009	+			+	+	+	+	+
T6_2008	+			+	+	ns	ns	+
T6-2009	+			+	+	+	+	+
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 9: Percentage plumpness of all treatments per variety 2007

	SSG 564	SSG 506	S02-11	Erica	Nemesia	S5
T1	85.1b	97.4a	86.6c	72.2b	63.7b	82.1b
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	89.6abc	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 10: 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 11: Percentage plumpness of all treatments per variety 2009

	SSG 564	Erica	Nemesia	S5	S6	S7
T1	93.8a	91.1c	89.6d	94.5b	92.0b	96.9a
T2	92.6a	94.3a	93.3c	95.7ab	94.6a	96.7a
T4	94.0a	93.5ab	95.8a	95.1b	93.3ab	97.4a
T5	95.0a	91.9bc	93.8bc	94.7b	94.6a	95.8a
T6	93.7a	94.8a	95.5ab	97.1a	93.8ab	97.6a
CV	1.9	1.9	1.9	1.9	1.9	1.9
LSD ($T_{0.10}$)	1.9	1.9	1.9	1.9	1.9	1.9
LSD ($T_{0.05}$)	2.5	2.5	2.5	2.5	2.5	2.5

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 12: Summary of effect of treatments on Percentage plumpness

	SSG 564	SSG 506	S02-11	Erica	Nemesia	S5	S6	S7
T2_2007	ns	ns	ns	+	+	+		
T2_2009	ns			+	+	ns	+	ns
T3_2007	+	ns	+	+	+	+		
T4_2007	+	ns	+	+	+	+		
T4_2008	ns			ns	ns	ns	ns	ns
T4_2009	ns			+	+	ns	ns	ns
T5_2007	+	ns	ns	+	+	+		
T5_2008	ns			ns	ns	ns	ns	ns
T5_2009	ns			ns	+	ns	+	ns
T6_2008	ns			ns	ns	ns	-	-
T6_2009	ns			+	+	+	ns	ns
T7_2008	+			+	ns	ns	ns	ns

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

Table 13: 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 14: 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 15: Kernel nitrogen of all treatments per variety, 2009

	SSG 564	Erica	Nemesia	S5	S6	S7
T1	1.72b	1.63b	1.65abc	1.56b	1.6b	1.53b
T2	1.71b	1.58b	1.61bcd	1.51b	1.59b	1.55ab
T4	1.65b	1.6b	1.55d	1.48b	1.48c	1.59ab
T5	1.78a	1.76a	1.69ab	1.68a	1.72a	1.60ab
T6	1.78a	1.68ab	1.73a	1.65a	1.65ab	1.62a
CV	4.4	4.4	4.4	4.4	4.4	4.4
LSD ($T_{0.10}$)	0.08	0.08	0.08	0.08	0.08	0.08
LSD ($T_{0.05}$)	0.10	0.10	0.10	0.10	0.10	0.10

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

Table 16: 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		
T2_2009	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
T4_2009	ns			ns	–	ns	–	ns
T5_2007	ns	ns	ns	ns	ns	ns		
T5_2008	ns			+	ns	ns	ns	ns
T5_2009	+			+	ns	+	+	ns
T6_2008	+			+	ns	ns	ns	ns
T6_2009	+			ns	ns	+	ns	+
T7_2008	+			+	ns	ns	ns	ns

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

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

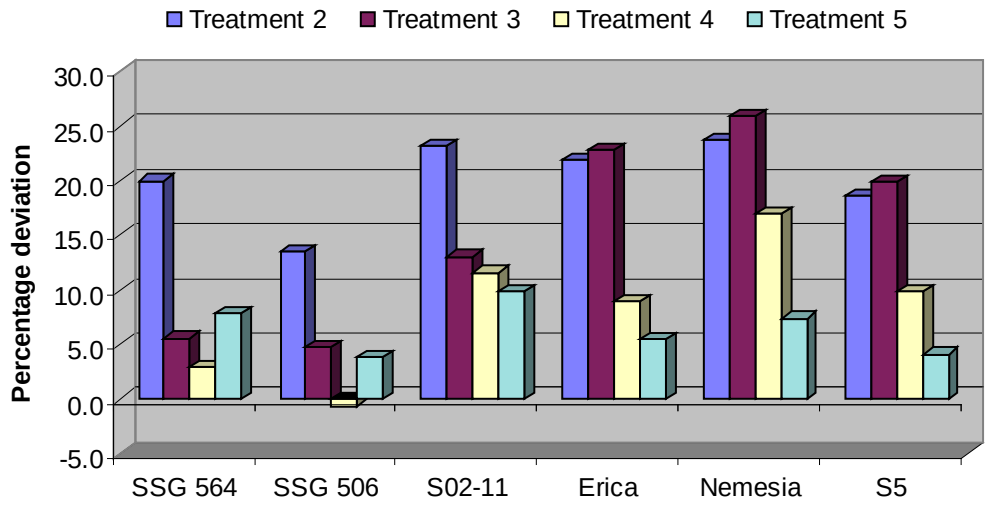


Figure 3: Percentage deviation in yield from unsprayed control with different treatments for the 2008 season.

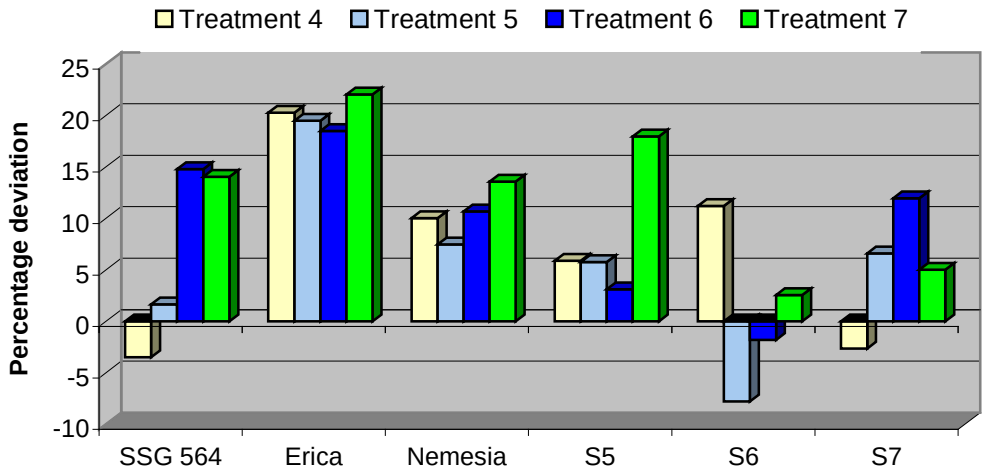


Figure 4: Percentage deviation in yield from unsprayed control with different treatments for the 2009 season.

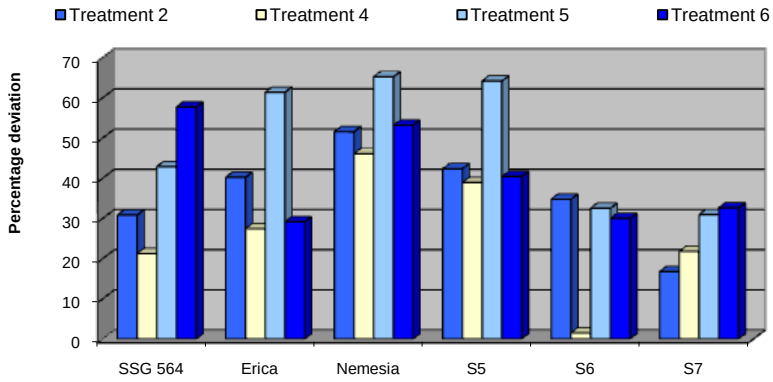
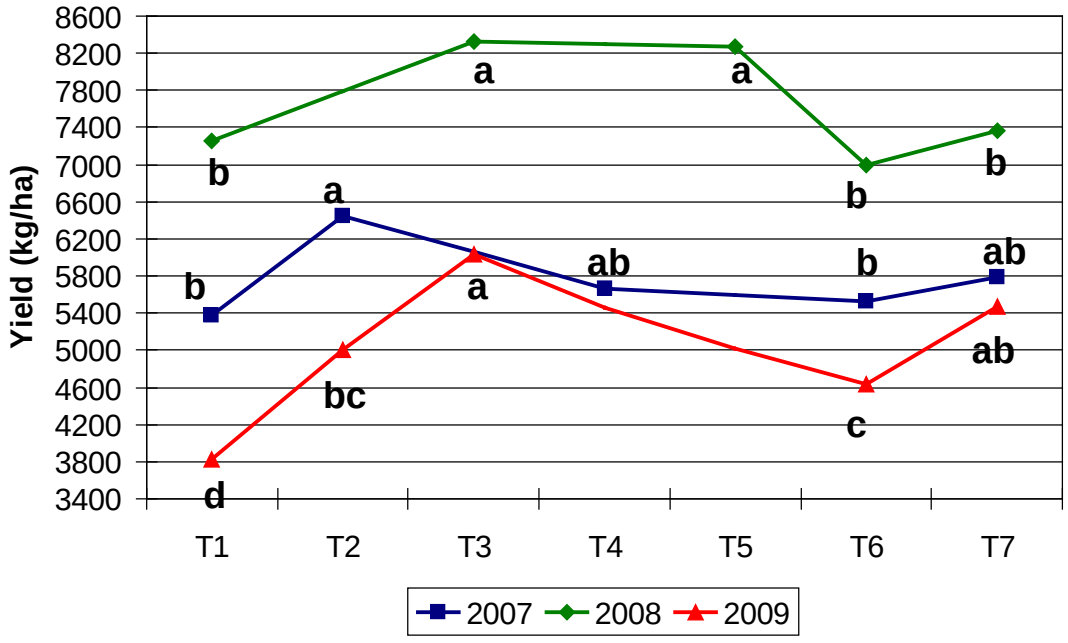
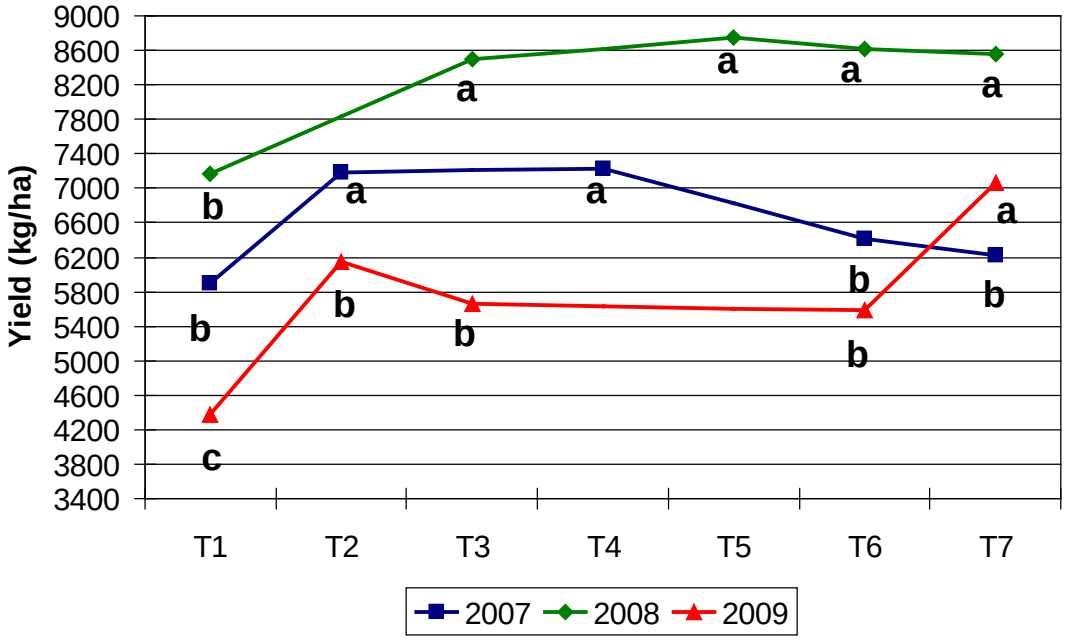


Figure 5: Change in yield (kg/ha) of SSG 564 with different treatments



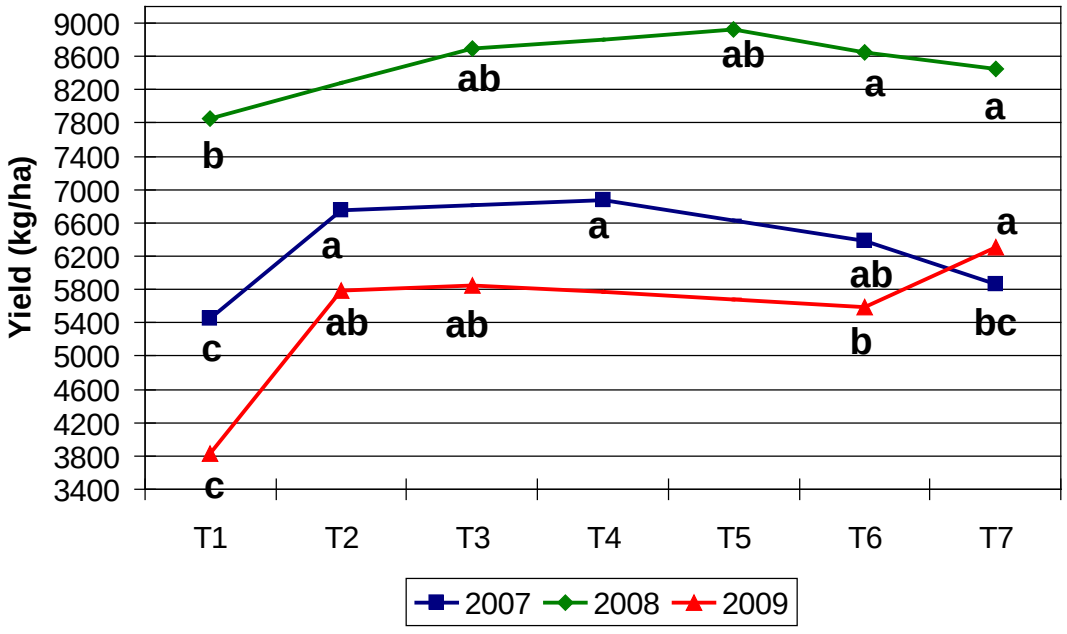
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

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



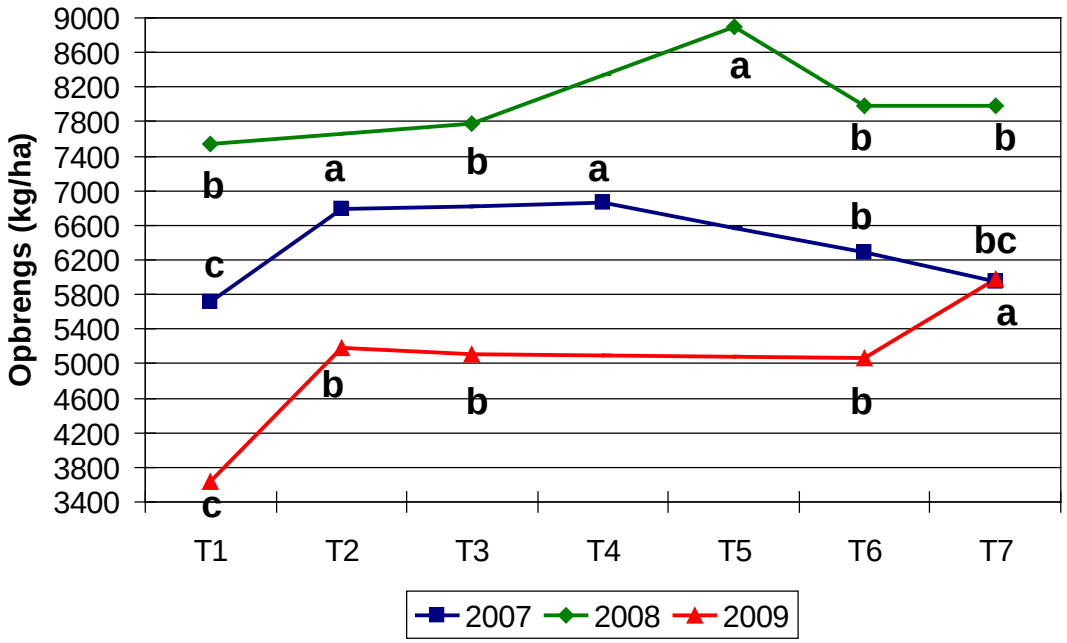
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

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



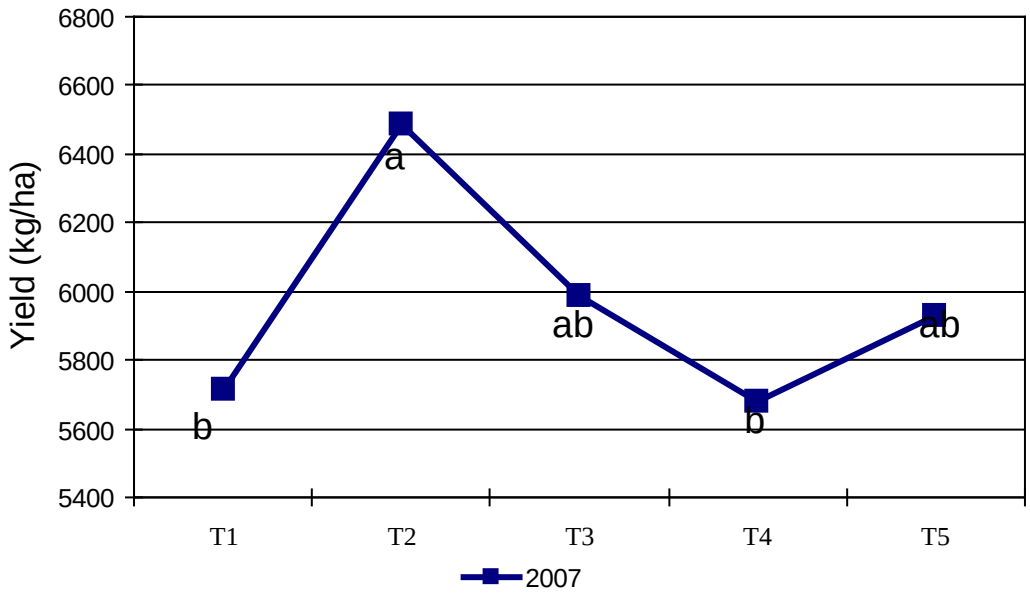
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 8: Change in yield (kg/ha) of S5 with different treatments



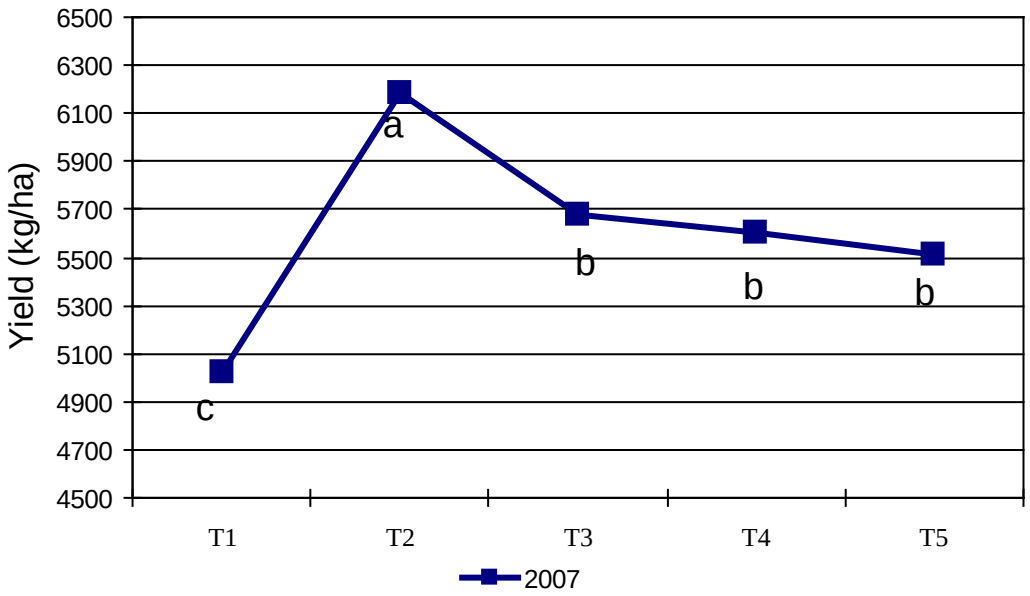
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 9: Change in yield (kg/ha) of SSG 506 with different treatments



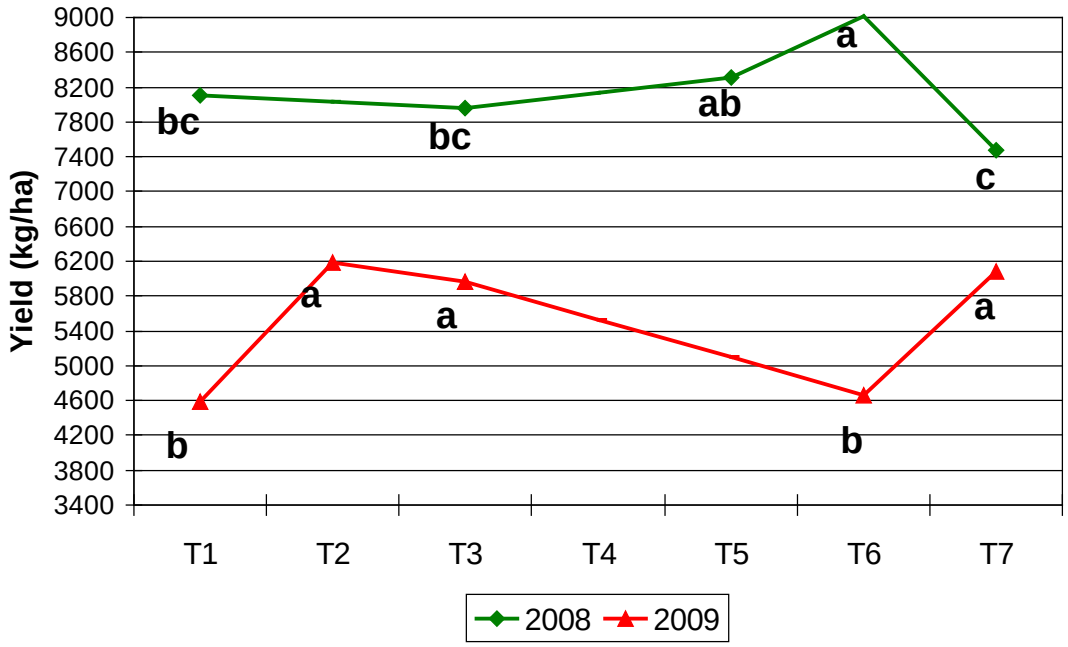
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 10: Change in yield (kg/ha) of S02-11 with different treatments



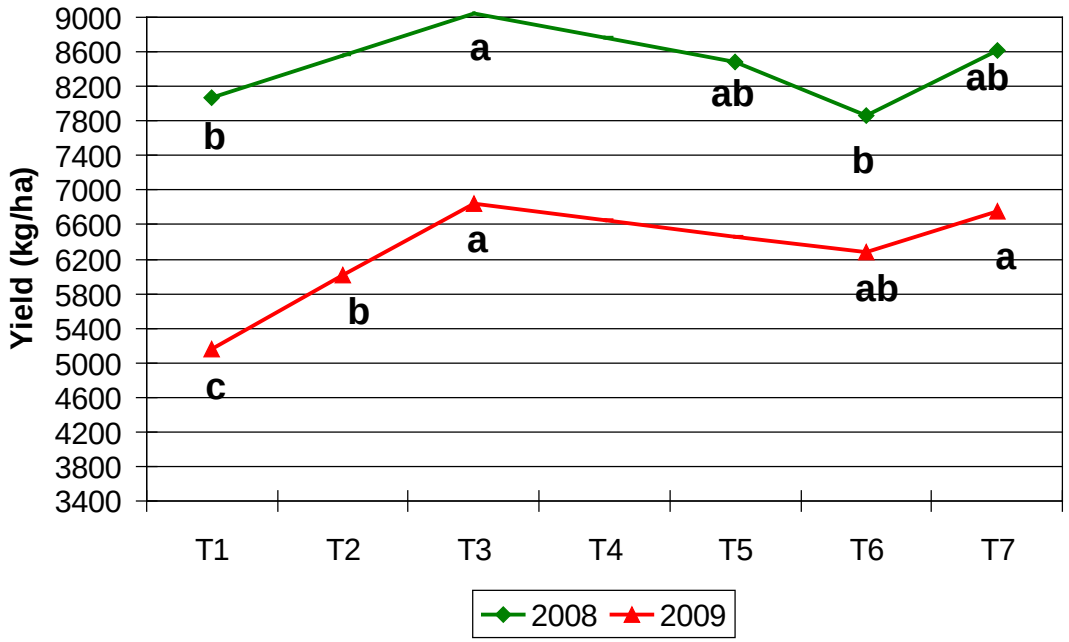
Different letters after the data implies that there is a significant difference between the two values at a 95% confidence

Figure 11: 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 12: 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 13: Deviation of income difference (R/ha) of treatments calculated as a percentage of the control, 2007

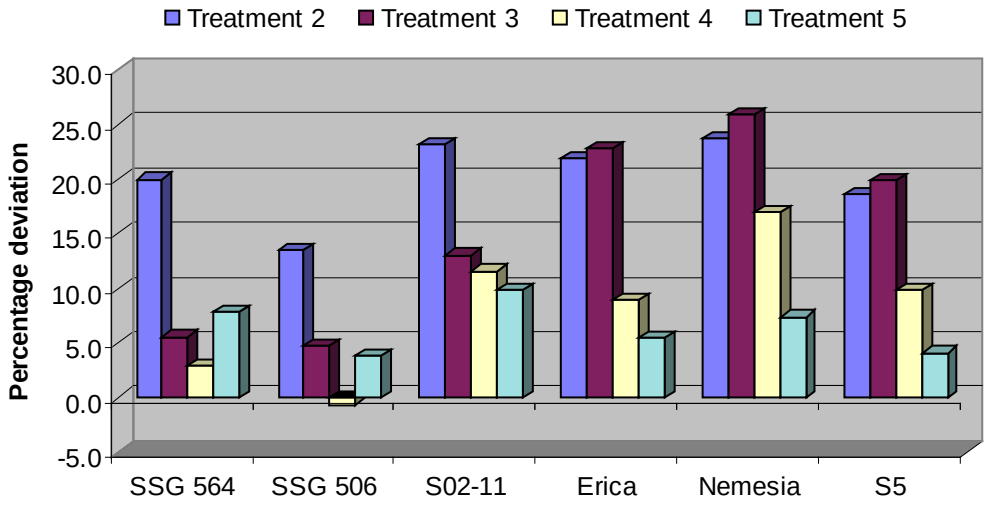


Figure 14: Deviation of income difference (R/ha) of treatments calculated as a percentage of the control, 2008

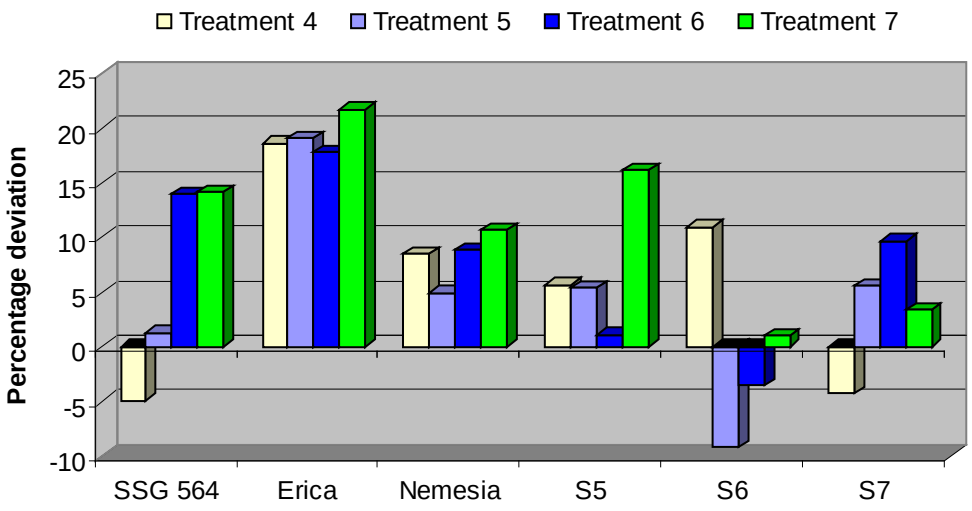


Figure 15: Deviation of income difference (R/ha) of treatments calculated as a percentage of the control, 2009

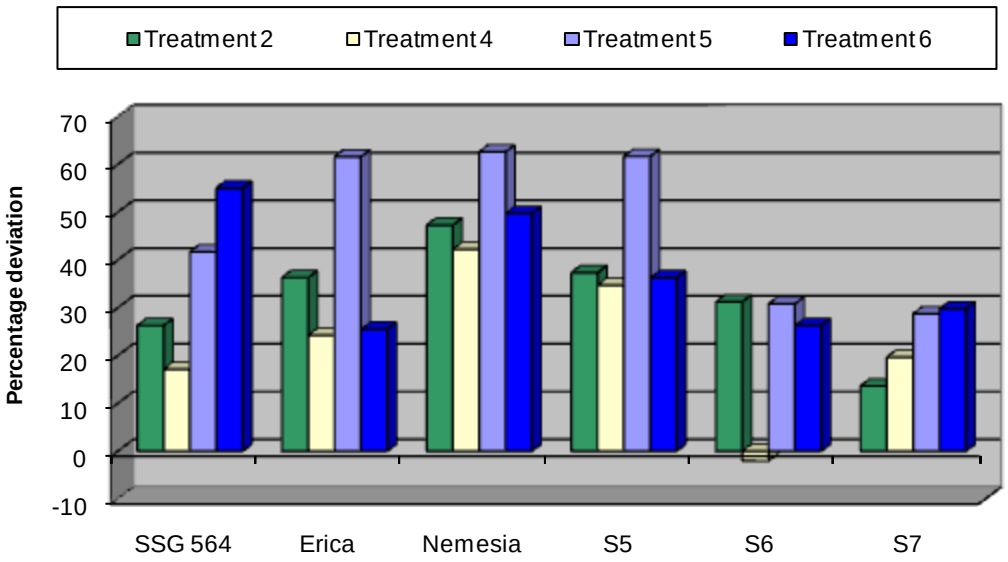


Figure 16: Net blotch readings for varieties with different treatments (0 = no visible disease; 9 = whole leaf infested) for the 2007 season

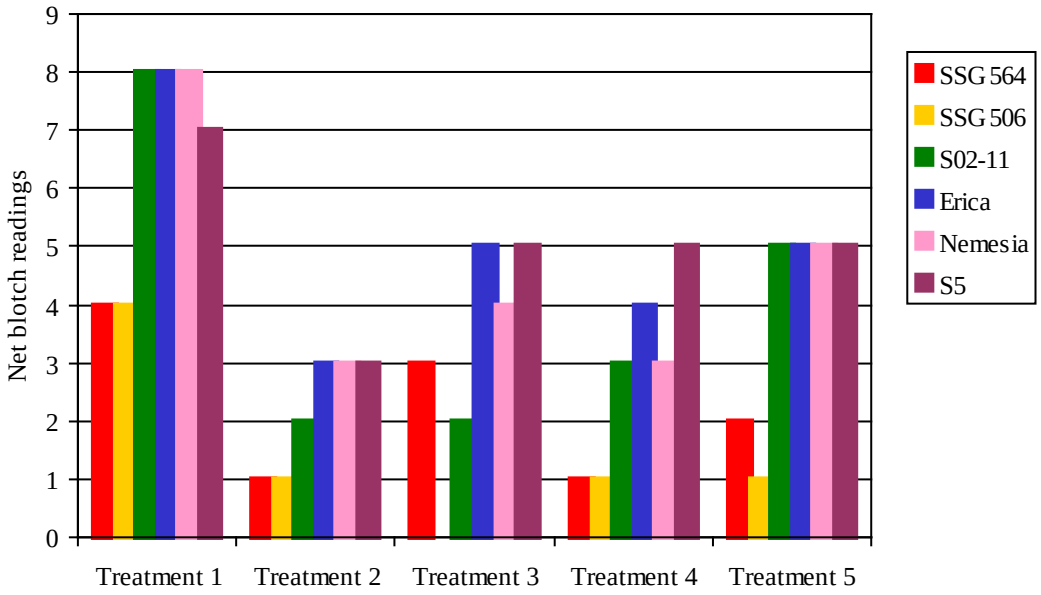


Figure 17: Net blotch readings for varieties with different treatments (0 = no visible disease; 9 = whole leaf infested) for the 2008 season

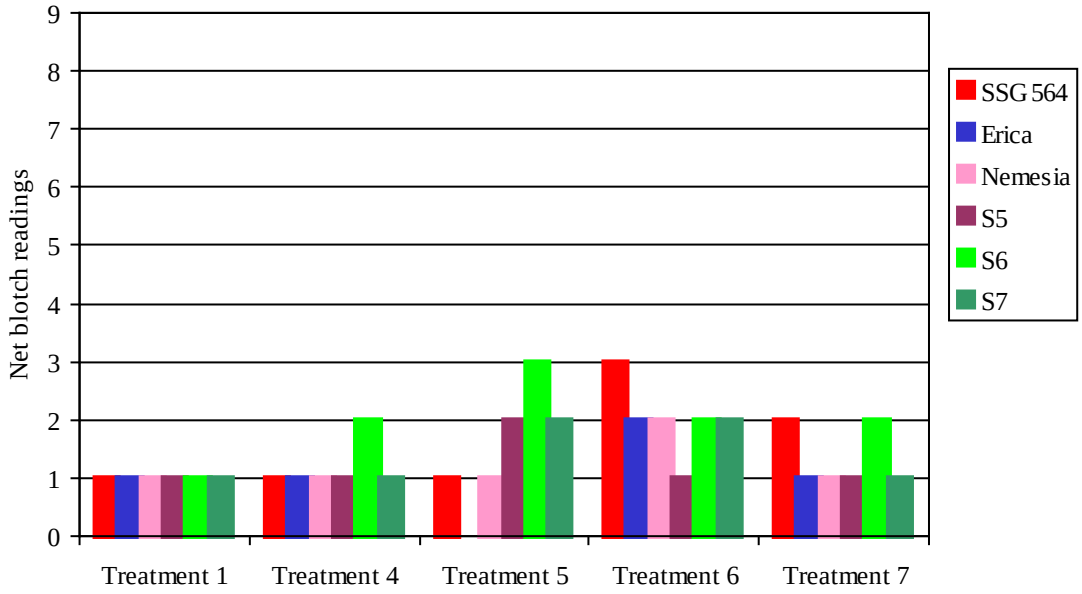


Figure 18: Net blotch readings for varieties with different treatments (0 = no visible disease; 9 = whole leaf infested) for the 2009 season

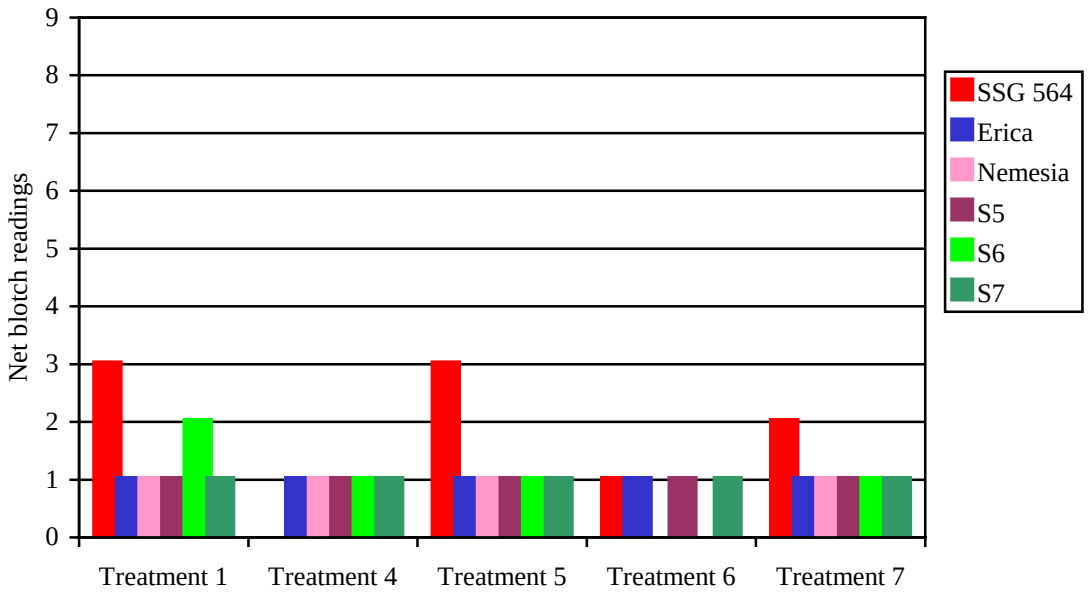


Figure 19: Scald readings for varieties with different treatments for the 2007 season (0 = no visible disease; 9 = up to the flag leaf)

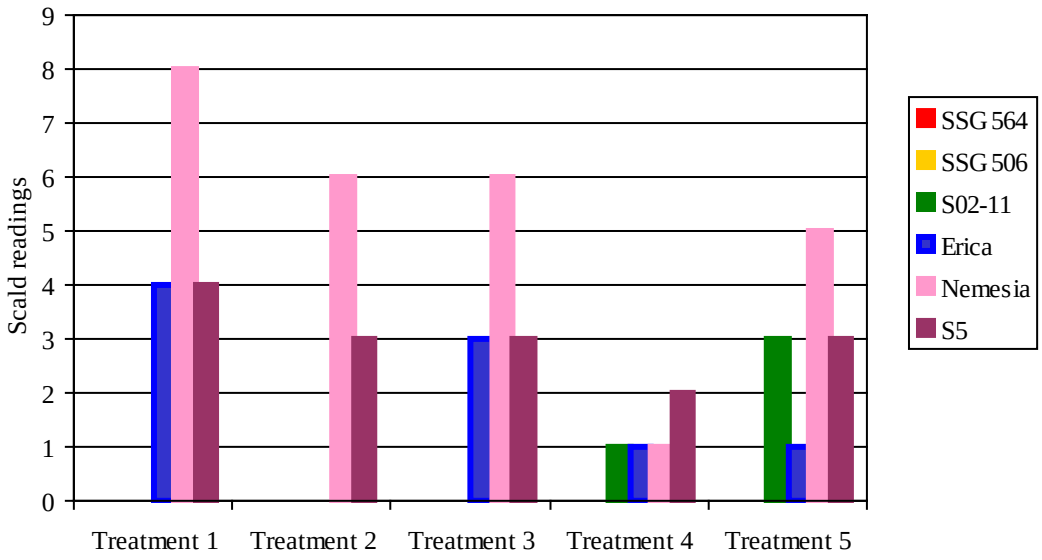


Figure 20: Scald readings for varieties with different treatments for the 2008 season (0 = no visible disease; 9 = up to the flag leaf)

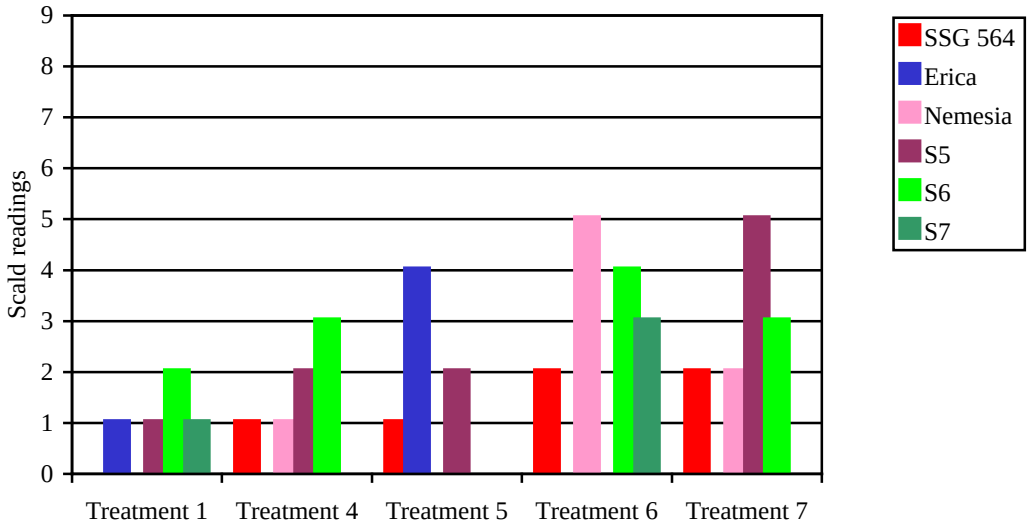
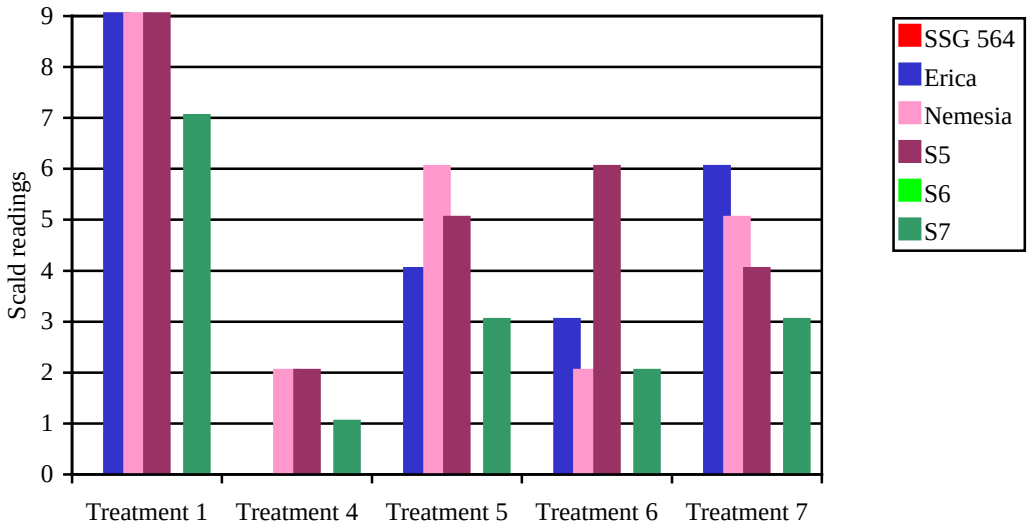


Figure 21: Scald readings for varieties with different treatments for the 2009 season (0 = no visible disease; 9 = up to the flag leaf)



Discussion

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

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. During 2007, net blotch only established late in the season which explains why the treatments with a second application of strobilurin performed better. In 2008 the disease pressure was extremely low, and the results confirmed the beneficial effects of fungicides in the absence of fungal diseases. Leaf blotch was the predominant fungal disease in 2009 and all treatments only delivered positive results.

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 determine varietal 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 2009 data shows clearly, that there are differences in the degree of resistance to leaf blotch between the varieties. SSG 564 and S6 showed good resistance, S7 moderate susceptibility with the other three highly susceptible.

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

7. It is important to spray the recommended dosage to prevent resistance to strobilurin based fungicides. For the same reason it is also important to spray preventative rather than curative.

8. To ensure that the disease pressure does not build up to uncontrollable levels, it is advised to apply the first fungicide six to nine weeks after planting.

9. The data shows the best practice is to apply a strobilurin containing fungicide first, while the second application depends on the disease pressure and pathogen. In the case of high Net blotch disease pressure a second strobilurin containing fungicide would be advised, or in the case of other pathogen (leaf blotch) or low net blotch incidence a triazole containing fungicide can be used.