RUSTWATCH

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SUMMARY

The Rustwatch partners carried out and reported 12 trials in 10 different countries during 2020, despite of Covid 19 restrictions. In a few cases, the provided trial protocol has been adjusted to fit with local activities, which means that only 10 of the 12 trials can be fully summarized. Yellow rust and brown rust developed differently: seven trials had attack of yellow rust and 4 trials attack of brown rust. Employing a split plot design, four cultivars were tested using different control strategies to minimize outbreak of rust diseases and associated yield losses. Each trial included a rust susceptible cultivar, a cultivar with low risk of severe attack (slow ruster), a rust resistant cultivar and a mixture of these three cultivars. For each cultivar, a full fungicide program (Treatment frequency index (TFI) = 2) was tested and compared with the control achieved using reduced rates of fungicides (TFI=1), alternative chemistry and the use of control thresholds. Full or fully acceptable control was achieved from traditional chemistry using four treatments with both normal and reduced rates. In comparison, the control from the strategy using four treatments with alternative chemistry (The BCA product Serenade (*Bacillus subtillis*) and Sulphur in alternation) gave only poor or generally insufficient control. Use of Decision support systems (DSS) provided reliable and good control when assessing the need for control of yellow rust. In some trials other diseases than rust developed significant attack. However, the used DSS in the trials only addressed rust diseases, which may lead to an unbalanced result for this strategy. Cultivar mixtures reduced the attack compared to the average of the 3 individual cultivars. The benefit from the mixtures was most pronounced in untreated plots, where attack was reduced by 23%, while it was reduced by 5% in strategies with poor control. Yield data indicate that reduced rates were sufficient for control of even severe rust attacks providing the best net yield results. The high input has in comparison been too expensive and not economically sustainable. The insufficient control from the alternative strategy is also reflected in an unacceptably low yield response and as the cost of the alternative chemistry is still significant the net yield results becomes negative. On average yield responses from the DSS-system were moderate. This reflects variable input scenarios for handling the diseases. Still the DSS provided an overall good output as the cost of fungicides were lower and net yields were only a little behind the treatment using reduced rate. The trial activity will continue in 2021 following the main trends from 2020. If new alternative products can be found these may replace the treatments from 2020, which only provided insufficient control.

Aim of activity

The aim of this activity was to investigate different IPM control strategies for control of yellow rust/brown rust in different countries and regions. The wish has been to include the use of both resistant cultivars, cultivar mixtures, use of control thresholds (tr 5), use of reduced fungicide rates (tr 3) and alternative chemistries (tr 4). The intension has also been, where possible, to include the trials as part of the demonstration activities and case-studies organized in certain countries.

Materials and methods

Field trials were carried out in winter wheat in 10 countries (Figure 1) according to the 'Protocol for IPM trials harmonized and validated by partners (M3.11)'. Each partner in the project was asked to provide field trials with different cultivars (Table 1). Each country was free to choose the three cultivars as representative for their country/region: A: one resistant, B: one slow ruster and C: one moderately susceptible cultivar and D: a mixture of the 3 cultivars A+B+C. See illustration in Figure 2.

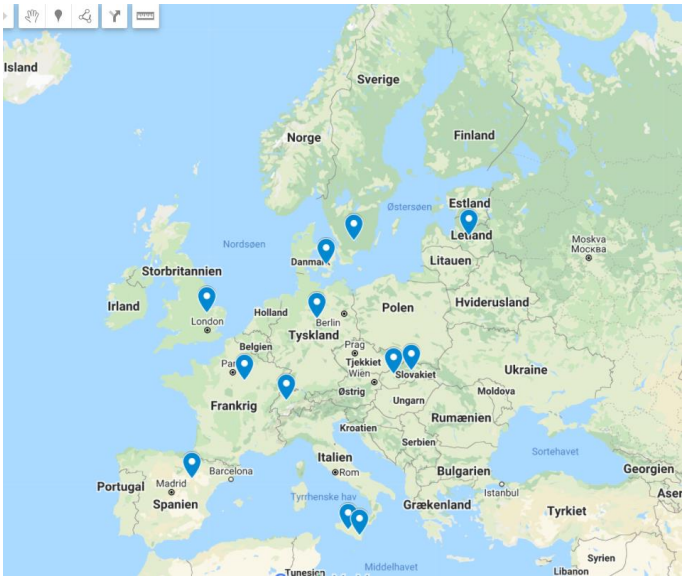

Figure 1. Map with rust trial locations in 2020

Table 1. List of trials carried out in 2020

	cultivars			Trial Carried out	contact person
Country	resistant	slow rust	Susceptible rust		
DK	Informer	Sheriff	Benchmark	1	Lise N Jørgensen, AU
SW	Informer	Julius	Memory	1	Ida Lindell (HIR Skåne)
F	None?	None?	Grapelli	1	Claude Maumene, Arvalis
UK	Crusoe	KWS Zyatt	JB Diego	1	Jane Thomas/Bill Clark, NIAB
DE	Informer	Sheriff	Rumor	1	Bettina Klocke; JKI
SL	PS Jeldka	PS Pugua	PS Sunanka	2	Svetlana Slikova
LA	Informer	Kalmar	Julius	1	Janis Jasko,
ES	Nudel	Filon	Camargo	1	Nerea Arias/Jesús Zuñiga INTIA
IT	467175	Aureo	Monastir	1 SR	Biagio Randazzo
IT	Iride	Monastir	Tirex	1 YR	Biagio Randazzo
CH	Several cultivars			2	Fabio Mascher, Agroscope

Figure 2 : Illustration of principles behind the use of cultivar mixtures on disease development (Kristoffersen et al 2020). Left side: cultivar mixture; right side: susceptible cultivar, slow ruster and resistant cultivar, from left to right.

The tested cultivars are listed in table 1 along with the responsible persons and institutions. The trials were placed as split-plot trials with 3 replicates. Factor 1 was cultivar and Factor 2 was fungicide treatments. For each of the tested cultivars, 5 different treatments were compared using both standard chemistry, reduced rates of chemistry, alternative chemistry and treatments based on DSS (Table 2).

Table 2. Recommended treatments in the IPM rustwatch trial with 5 treatments in each of the 4 cultivars.

Treatments	**GS 31-32**	**GS 33-37 + 10 days**	**GS 45-51 + 10 days**	**VS 65 + 10 days**	**TFI**
1. Untreated					
2. high input	0,6 Comet pro (0.5 TFI)	0,75 Balaya** (0,5 TFI)	0.5 Elatus ERA (0.5 TFI)	0.5 Folicur (0,5 TFI)	2.0
3. low input	0,3 Comet Pro (0.25 TFI)	0,375 Balaya** (0, 25 TFI)	0,25 Elatus ERA (0,25 TFI)	0,25 Folicur (0,25 TFI)	1.0
4. Spray with alternative chemistries	7 l/kg Sulphur	4,0 l Serenade ASO	7 l/kg Sulphur	4,0 l Serenade ASO	
5. Spray when needed and use products relevant for the Growth stage and dose from tr. 2 or 3 *					

In eight of the trials the same protocol with treatments were tested. In two of the trials reduced numbers of elements were tested so it was not possible to compare the effects directly.
Table 8 and 9 (Appendix) provides a summary of the main information from the individual trials including dates for sowing, treatments and harvest. Table 7 (Appendix) gives a more detailed description of each trial, including information on the main weather conditions during the season. Table 10 summarizes the collected data for comparison.
The cost of treatments (treatments + application) has been calculated based on cost assumptions (150 €

for tr 2 and 95 € for tr 3. Which means that yield benefits should be 9.5 dt/ha and 6 dt/ha in order to provide positive net yield responses. The cost of the alternative chemistry is difficult to estimate as particularly Sulphur has variable cost. In this project the cost is estimated to be in line with the full rate in tr. 2 (9.5 dt/ha). The DSS has used variable input going from none to 3 treatments. The average cost is estimated to 3 dt/ha.

Results

Overall data from the trials with the same protocol is summarized in table 3 and 4. These tables do not include data from France and Switzerland, which used a reduced or different protocol.
As expected, yellow rust and brown rust dominated the diseases in the trials. A few of the trials also developed attack of septoria tritici blotch (3 trials with ca. 10% attack on F-1 (leaf one from the top), tan spot (1 trial with 15% attack on L2) or powdery mildew (1 trial with 5% attack on F-1). An extract from the program ARM is shown in Table 5 and 6 summarizing data across all trials.

Control of rust

Ten of the trials developed some attack of yellow rust. However only seven of the 10 trials with common protocol could be summarized (Table 3) and also create background for the data in figure 3. Only five of the eight trials with common protocols developed significant attack of yellow rust (10-85%).
The following major points below can be concluded from the control of **yellow rust** in the trials.

- As expected, the cultivar categorized as susceptible developed most severe attack. The slow ruster developed a more moderate attack in line with the mixture. No or very little rust was seen in the resistant cultivar.
- The high input treatments with four applications provided full control of yellow rust in all trials.
- The strategy using reduced rates – using input with half the rates of standard treatment - provided similarly full control even in the most susceptible cultivars.
- The strategy using alternative chemistry with Serenade and Sulphur provided insufficient control of yellow rust - where attacks were severe.
- The strategy using DSS as guidance for treatments provided good control and could keep the total input down to fewer treatments.
- The attack of yellow rust in the mixtures compared with the average of the 3 cultivar components was either similar or slightly lower in the cultivar mixture. Figure 5 shows the variation in attack from untreated cultivars – comparing the 4 cultivars and the average of the 3 solo cultivars. Figure 6 shows the difference between attack in the mixture and the average of 3 solo cultivars for all control strategies.

The following major points could be seen from the control of **brown rust** in the trials. As also summarized in Table 3 and figure 4.
Four trials developed relative moderate to minor attack of brown rust. Maximum attack in untreated plots reached approx. 14 % on flag leaves in the most susceptible cultivar.

- All tested cultivars at the four locations developed low to moderate attack of brown rust. The cultivars were apart from one locality not chosen based on their resistance to brown rust.
- The high input strategy with four applications provided full control of brown rust in all trials.
- A strategy using reduced rates – using input with half the rates of standard treatment - provided similarly full control.
- The strategy using alternative chemistry with Serenade and Sulphur provided insufficient control of brown rust

- The strategy using DSS as guidance for treatments provided only moderate control, as a result of recommendations mainly having focused on yellow rust control and not brown rust.
- The attack of brown rust in the mixtures compared with the average of the 3 components was either similar or slightly lower in the mixture. Leaf 1: 3.4% versus 4.0% or leaf 2: 3.4% versus 3.4%.

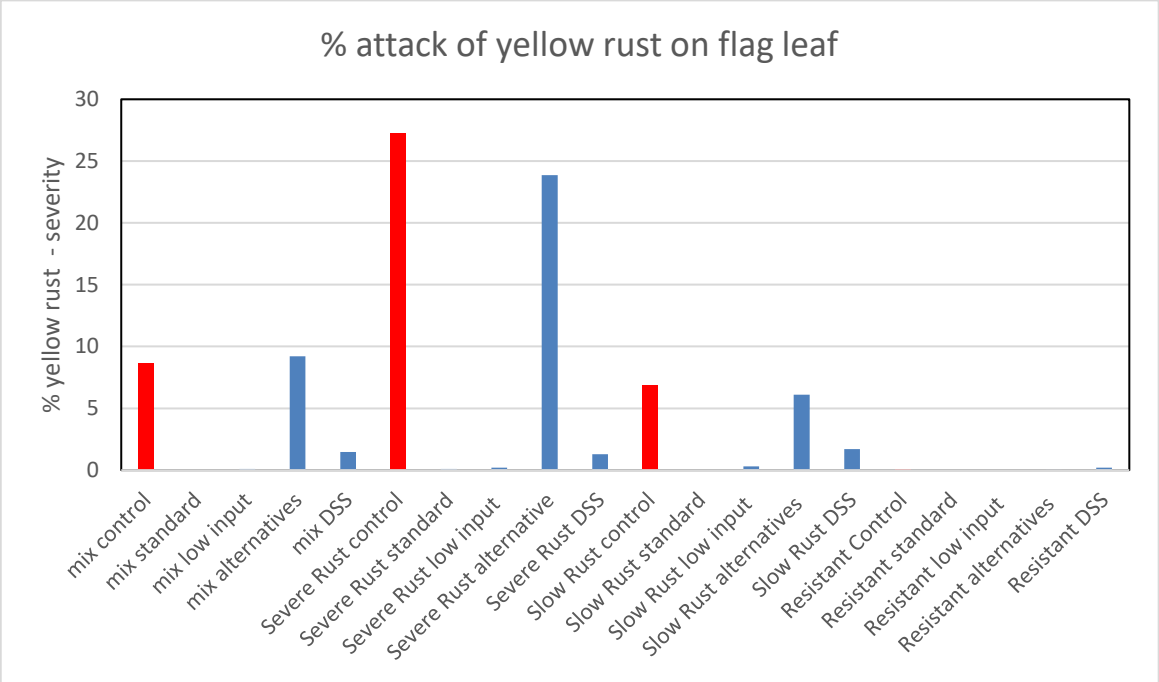

Figure 3. % attack of yellow rust on flag leaf assessed at GS 75-77. Data represents the average of 8 trials. Red bars shows attack in the 4 untreated cultivars.

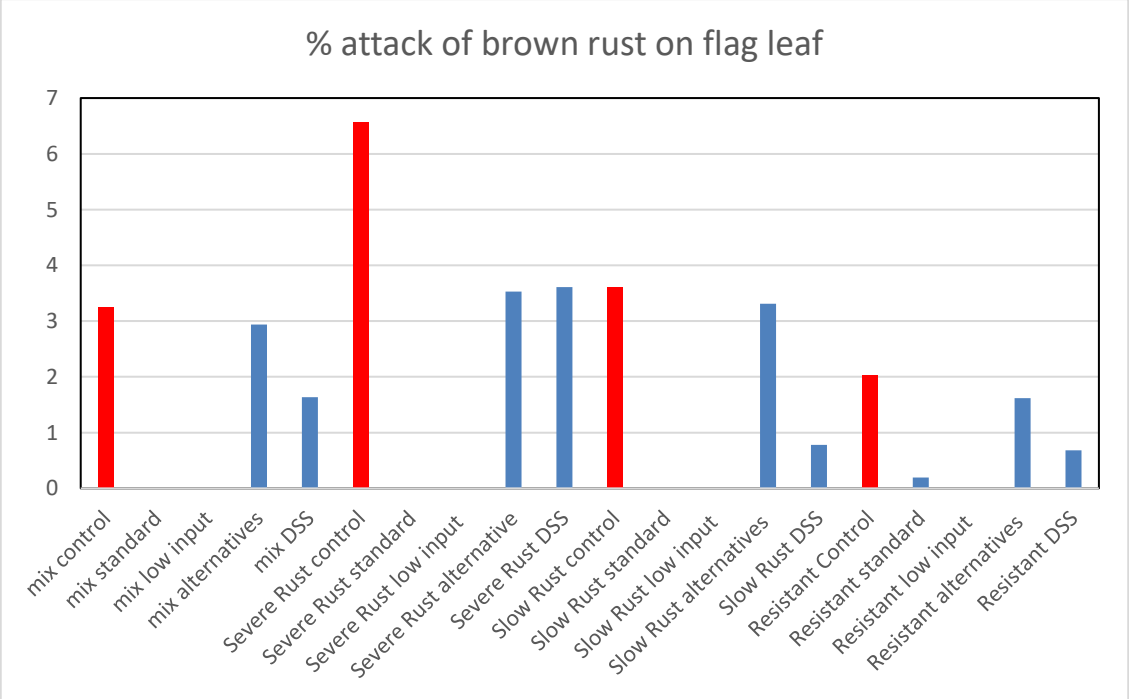

Figure 4: % attack of brown rust on flag leaf assessed at GS 75-77. Data represents the average from 4 trials. Red bars shows attack in the 4 untreated cultivars.

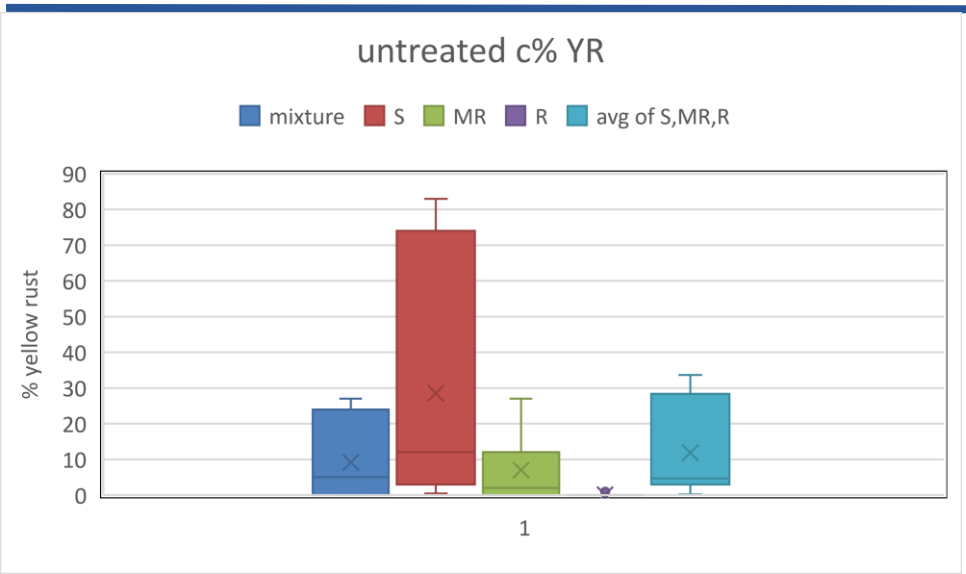

Figure 5. Results from 7 IPM trials carried out in 2020. Percent yellow rust at GS 75**.** Average attack in mixture=9.1%; susceptible =28.5%; slow ruster=7.0%, Resistant=0% and Average of 3 single cultivars = 11.9%.

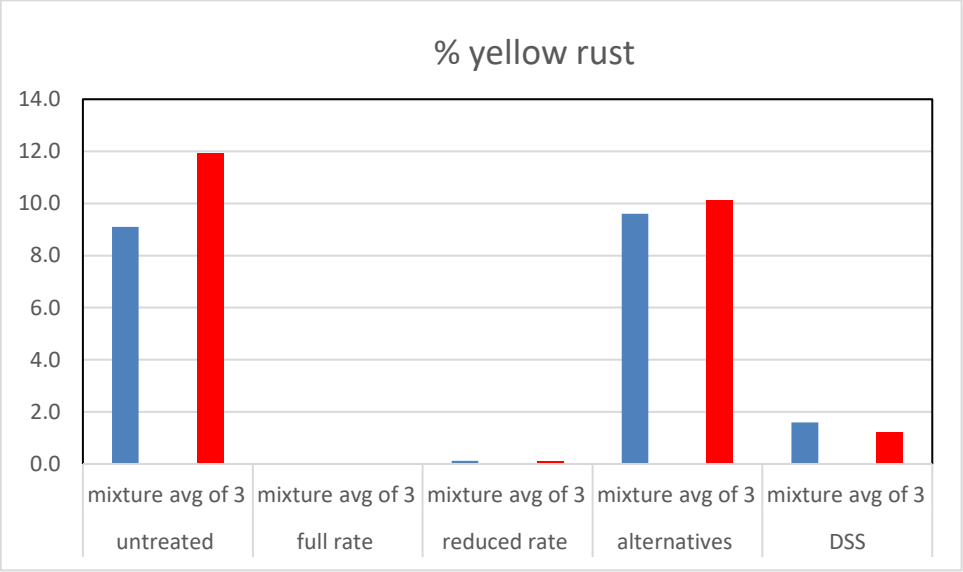

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Figure 6: Average attack of yellow rust in mixture and as average of 3 cultivars. (7 trials 2020)

Untreated susceptible wheat (Benchmark)

Variety mixture with 3 cultivars including Benchmark

Pictures . Attack of yellow rust in untreated Benchmark and in variety mixture including Benchmark

Yield responses

Ten trials following the same protocol were summarised in Table 3 and 6. As average of the 10 trials the following can be extracted (Table 3, 3a, 4, 4a, 5, Figure 7 and 8).

- Yield levels were generally high in the trials, but still varying in untreated between 50 and 115 dt/ha.
- The strategy using high rates – with four applications – provided together with the strategy using reduced rates similar yield responses. On average the response was 7 dt/ha.
- In two trials with most severe attack the increase was 30 DT/ha. This was similarly seen following both high and low input (Table 4 and 4a).
- The strategy using alternative chemistry with Serenade and Sulphur provided insufficient control and also a very low and not significant yield response.
- The strategy using DSS as guidance for treatments provided only moderate yield responses. This reflect a big variation between the specific input. In several cases no applications have been made using DSS, which can be reflected in both control and yields.
- When net yields are calculated in the trials the reduced rates comes out with the overall best net yield result in line with the DSS testing. Full input have been too expensive, and similarly the alternative chemistry have been both inefficient and too expensive (Table 3a).
- In the two trials with most severe attack of yellow rust the same trend was seen – but her the net yield returns have been 10-15 dt/ha, but again the reduced rates provided the best results (Table 4a).

Table 3: Yield and yield increases (dt/ha) in 10 trials with 4 cultivars and variable attack of yellow rust.

	mixture	rust susceptible	slow rust	rust resistant	average 3 single	Average all
Control	77,6	74,8	76,9	79,7	77,2	77,3
standard	+8,3	+9,1	+6,3	+5,1	+6,8	+7.2
low input	+7,1	+10,6	+6,6	+6,1	+7,8	+7.6
alternatives	+0,2	+2,5	+1,1	+2,8	+2,1	+1.7
DSS	+4,4	+8,6	+4,3	+1,3	+4,8	+4.7
LSD_{95}	2,6					

Table 3a: Yield and net yield increase (dt/ha) in 10 trials with 4 cultivars and variable attack of yellow rust. (Cost of tresatment and chemisty has been deducted)

	mixture	rust susceptible	slow rust	rust resistant	average 3 single	Net yield Average all
Control	77,6	74,8	76,9	79,7	77,2	77,3
standard	-1.1	-0.3	-3.1	-4.3	-2.6	-2.2
low input	1,1	4.6	+0.6	+0.1	+1.8	+1,6
alternatives	-9.2	-6.9	-8.3	-6.6	-7.2	-7.8
DSS	1.4	5.6	+1.3	-1.7	+1.7	+1.7

Table 4: Yield and net yield increases (dt/ha) in 2 trials with most severe attack of yellow rust (DK and ES trial).

	mixture	rust susceptible	slow rust	rust resistant	Average 3 single	average
Control	83,9	75,4	89,3	84,2	83,0	83,2
standard	+18,7	+29,8	+16,9	+14,5	+20,4	+20,0
low input	+18	+31,5	+16,2	+16,0	+21,2	+20,4
alternatives	+2,3	-2,6	+0,9	+5,8	+1,4	+1,6
DSS	+14,5	22,2	+15,6	+1,3	+13,0	+13,4
LSD_{95}	4,9					

Table 4a: Yield and net yield increase (dt/ha) in 2 trials with most severe attack of yellow rust (DK/ES).

	mixture	rust susceptible	slow rust	rust resistant	Average 3 single	Net yield average
control	83,9	75,4	89,3	84,2	83,0	83,2
Standard**	+9.3	+20.4	+7.5	+5.1	+11.0	+10.6
low input	+12.0	**+25.5**	**+10.2**	**+10.0**	**+15.2**	**+14.5**
alternatives	-7.1	-12.0	-8.7	-3.6	-7.8	-7.9
DSS	+11.5	+19.2	+12.6	-1.7	+10.0	+10.4

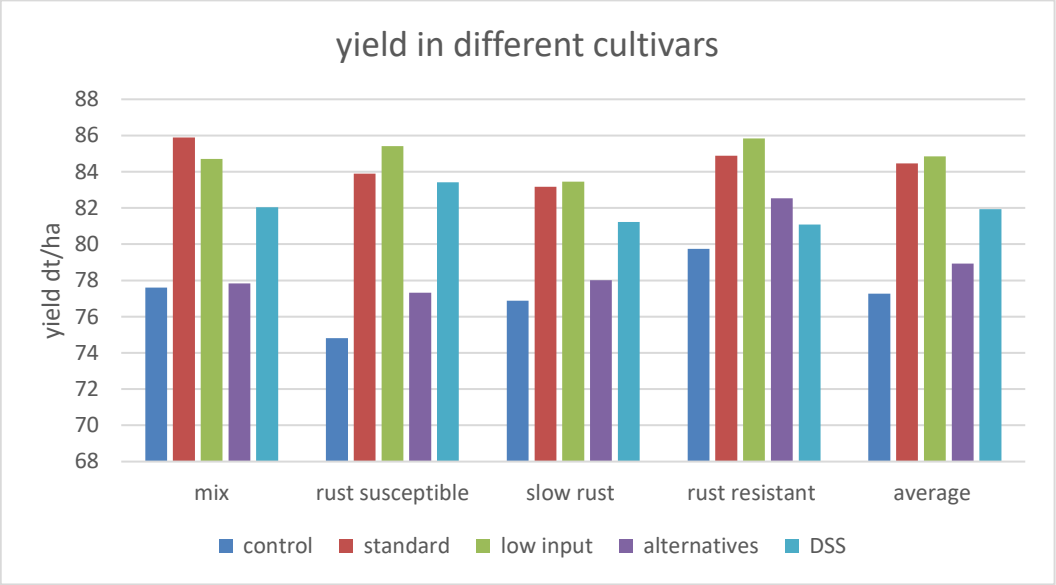

Figure 7: Yield responses (dt/ha) in the 4 cultivars following 5 different strategies.

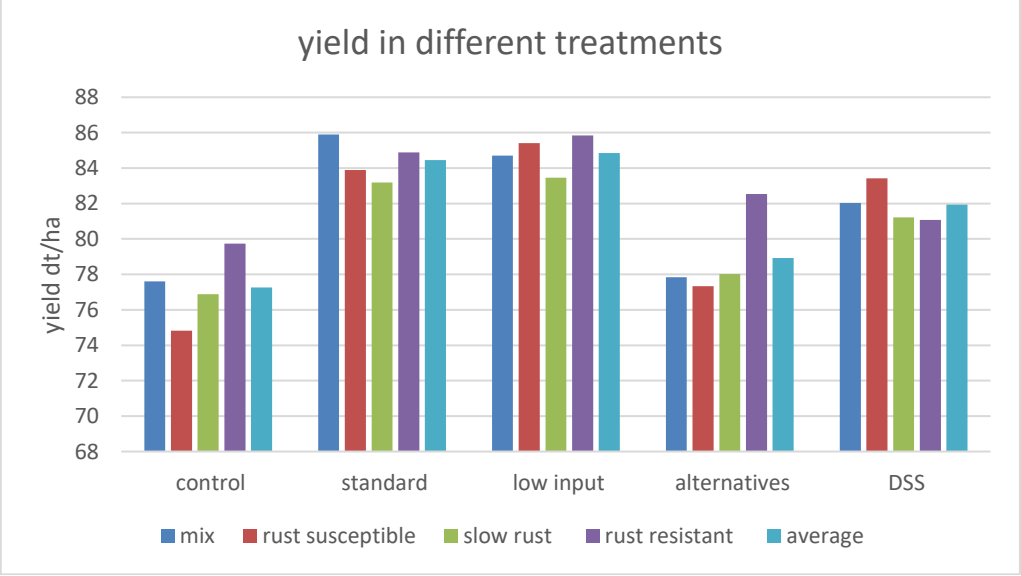

Figure 8: Yield responses (dt/ha) in the 5 different strategies with different cultivars

References

Kristoffersen, R. Heick, TM, Møller, G. Eriksen, LB. Nielsen, GC, Jørgensen, LN (2020) The potential of cultivar mixtures to reduce fungicide input and mitigate fungicide resistance development, Agronomy for Sustainable Development, 40:36 https://doi.org/10.1007/s13593-020-00639-y

Appendix

Table 5: Average yield, yield increases (dt/ha), TGW, specific weight and %Green leaf area (GS 77) from the trials in rust watch

Pest Type Pest Type Pest Code Pest Scientific Name Pest Name Crop Type, Code Crop Code BBCH Scale Crop Name Part Rated Part Rated Rating Type Rating Unit Crop Stage Scale Crop Stage Majority ARM Action Codes					C TRZAW BCER Winter wheat GRAIN C YIELD Q-MET *		C TRZAW BCER Winter wheat GRAIN C Y-INCREASE Q-MET *		C TRZAW BCER Winter wheat GRAIN C HLWEIGHT *		C TRZAW BCER Winter wheat GRAIN C TGW *		C TRZAW BCER Winter wheat C GRNARE *	
Trt No.	Treatment Name	Rate	Rate Unit	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count
1	Sortsblanding Untreated Check	(Blank) (Blank)	(Blank) (Blank)	77,61 gh	(10)	0,00 i	(9)	77,94 efg	(9)	41,06 fg	(10)	68,70 j	(8)
2	Sortsblanding Standard trt.	(Blank) (Blank)	(Blank) (Blank)	85,89 a	(10)	8,92 abc	(9)	78,38 c-f	(9)	42,07 cde	(10)	84,58 bcd	(8)
3	Sortsblanding Standard with low rates	(Blank) (Blank)	(Blank) (Blank)	84,71 abc	(10)	7,97 bcd	(9)	78,54 bcd	(9)	42,43 bcd	(10)	80,47 ef	(8)
4	Sortsblanding alternatives	(Blank) (Blank)	(Blank) (Blank)	77,84 gh	(10)	0,91 hi	(9)	77,78 g	(9)	40,74 g	(10)	73,85 hi	(8)
5	Sortsblanding PVO	(Blank) (Blank)	(Blank) (Blank)	82,04 def	(10)	5,13 ef	(9)	78,18 d-g	(9)	41,50 efg	(10)	71,48 ij	(8)
6	Severe Rust Untreated Check	(Blank) (Blank)	(Blank) (Blank)	74,82 i	(10)	0,00 i	(9)	76,23 i	(9)	38,45 ij	(10)	54,22 m	(8)
7	Severe Rust Standard trt.	(Blank) (Blank)	(Blank) (Blank)	83,89 a-d	(10)	9,30 ab	(9)	77,86 fg	(9)	39,49 h	(10)	77,74 fg	(8)
8	Severe Rust Standard with low rates	(Blank) (Blank)	(Blank) (Blank)	85,41 ab	(10)	11,30 a	(9)	78,21 d-g	(9)	39,38 h	(10)	77,29 fgh	(8)
9	Severe Rust alternatives	(Blank) (Blank)	(Blank) (Blank)	77,33 ghi	(10)	2,78 fgh	(9)	77,07 h	(9)	37,97 j	(10)	59,65 l	(8)
10	Severe Rust PVO	(Blank) (Blank)	(Blank) (Blank)	83,42 a-e	(10)	10,01 ab	(9)	78,45 b-e	(9)	39,31 hi	(10)	63,52 k	(8)
11	Slow Rust Untreated Check	(Blank) (Blank)	(Blank) (Blank)	76,89 hi	(10)	0,00 i	(9)	78,32 c-g	(9)	41,15 efg	(10)	75,51 gh	(8)
12	Slow Rust Standard trt.	(Blank) (Blank)	(Blank) (Blank)	83,18 b-e	(10)	6,08 de	(9)	78,92 ab	(9)	41,90 def	(10)	88,10 ab	(8)
13	Slow Rust Standard with low rates	(Blank) (Blank)	(Blank) (Blank)	83,46 a-e	(10)	6,38 cde	(9)	78,76 abc	(9)	41,20 efg	(10)	85,68 abc	(8)
14	Slow Rust alternatives	(Blank) (Blank)	(Blank) (Blank)	78,02 gh	(10)	1,01 hi	(9)	78,31 c-g	(9)	41,31 efg	(10)	79,77 ef	(8)
15	Slow Rust PVO	(Blank) (Blank)	(Blank) (Blank)	81,22 ef	(10)	4,99 efg	(9)	79,08 a	(9)	41,45 efg	(10)	80,42 ef	(8)
16	Resistant Untreated Check	(Blank) (Blank)	(Blank) (Blank)	79,74 fg	(10)	0,00 i	(9)	77,86 fg	(9)	43,04 b	(10)	78,68 efg	(8)
17	Resistant Standard trt.	(Blank) (Blank)	(Blank) (Blank)	84,88 abc	(10)	4,91 efg	(9)	78,23 d-g	(9)	44,41 a	(10)	88,63 a	(8)
18	Resistant Standard with low rates	(Blank) (Blank)	(Blank) (Blank)	85,84 a	(10)	6,01 de	(9)	78,44 b-e	(9)	44,96 a	(10)	86,31 ab	(8)
19	Resistant alternatives	(Blank) (Blank)	(Blank) (Blank)	82,53 cde	(10)	2,43 ghi	(9)	77,81 g	(9)	42,68 bcd	(10)	82,44 cde	(8)
20	Resistant PVO	(Blank) (Blank)	(Blank) (Blank)	81,08 ef	(10)	1,32 hi	(9)	77,80 g	(9)	42,94 bc	(10)	80,92 def	(8)
LSD P=.05 Standard Deviation CV				2,619 5,245 6,41		2,641 5,024 126,34		0,536 1,020 1,31		0,921 1,784 4,32		3,833 6,752 9,32	

Table 6: Average attack of brown rust and yellow rust in trials where these diseases were present.

				9		8		2		1	
Summary properties				Every		Every		Every		Every	
Pest Type				D		D		D		D	
Pest Type				Disease		Disease		Disease		Disease	
Pest Code				PUCCRT		PUCCRT		PUCCST		PUCCST	
Pest Scientific Name				Puccinia triticina		Puccinia triticina		Puccinia striiformis		Puccinia striiformis	
Pest Name				Brown rust of wheat		Brown rust of wheat		Striperust		Striperust	
Crop Type, Code				C		C		C		C	
Crop Code				TRZAW		TRZAW		TRZAW		TRZAW	
BBCH Scale				BCER		BCER		BCER		BCER	
Crop Scientific Name				Triticum aestivum		Triticum aestivum		Triticum aestivum		Triticum aestivum	
Crop Name				Winter wheat		Winter wheat		Winter wheat		Winter wheat	
Part Rated				L2		L1		L2		L1	
Part Rated											
Rating Type				PESSEV		PESSEV		PESSEV		PESSEV	
Rating Unit											
Crop Stage Scale				BBCH		BBCH		BBCH		BBCH	
Crop Stage Majority				71|75|77 *		75|77 *		75|77 *		75|77 *	
Trt No.	Treatment Name	Rate	Rate Unit	Mean	Count	Mean	Count	Mean	Count	Mean	Count
1	Sortsblanding Untreated Check	(Blank) (Blank)	(Blank) (Blank)	3,040 bc	(4)	3,257 b	(4)	11,76 b	(6)	8,66 cd	(8)
2	Sortsblanding Standard trt.	(Blank) (Blank)	(Blank) (Blank)	0,000 f	(4)	0,000 e	(4)	0,00 c	(6)	0,00 e	(8)
3	Sortsblanding Standard with low rates	(Blank) (Blank)	(Blank) (Blank)	0,000 f	(4)	0,000 e	(4)	0,01 c	(6)	0,10 e	(8)
4	Sortsblanding alternatives	(Blank) (Blank)	(Blank) (Blank)	2,048 cd	(4)	2,941 b	(4)	10,43 b	(6)	9,22 c	(8)
5	Sortsblanding PVO	(Blank) (Blank)	(Blank) (Blank)	1,671 de	(4)	1,634 c	(4)	2,20 c	(6)	1,47 e	(8)
6	Severe Rust Untreated Check	(Blank) (Blank)	(Blank) (Blank)	5,272 a	(4)	6,572 a	(4)	28,64 a	(6)	27,26 a	(8)
7	Severe Rust Standard trt.	(Blank) (Blank)	(Blank) (Blank)	0,000 f	(4)	0,008 e	(4)	0,00 c	(6)	0,10 e	(8)
8	Severe Rust Standard with low rates	(Blank) (Blank)	(Blank) (Blank)	0,000 f	(4)	0,000 e	(4)	0,00 c	(6)	0,21 e	(8)
9	Severe Rust alternatives	(Blank) (Blank)	(Blank) (Blank)	3,985 b	(4)	3,527 b	(4)	30,57 a	(6)	23,86 b	(8)
10	Severe Rust PVO	(Blank) (Blank)	(Blank) (Blank)	3,930 b	(4)	3,607 b	(4)	0,46 c	(6)	1,30 e	(8)
11	Slow Rust Untreated Check	(Blank) (Blank)	(Blank) (Blank)	3,846 b	(4)	3,615 b	(4)	12,97 b	(6)	6,82 cd	(8)
12	Slow Rust Standard trt.	(Blank) (Blank)	(Blank) (Blank)	0,000 f	(4)	0,000 e	(4)	0,00 c	(6)	0,00 e	(8)
13	Slow Rust Standard with low rates	(Blank) (Blank)	(Blank) (Blank)	0,000 f	(4)	0,000 e	(4)	0,27 c	(6)	0,30 e	(8)
14	Slow Rust alternatives	(Blank) (Blank)	(Blank) (Blank)	1,695 de	(4)	3,309 b	(4)	9,62 b	(6)	6,11 d	(8)
15	Slow Rust PVO	(Blank) (Blank)	(Blank) (Blank)	0,858 ef	(4)	0,783 d	(4)	1,95 c	(6)	1,70 e	(8)
16	Resistant Untreated Check	(Blank) (Blank)	(Blank) (Blank)	1,222 de	(4)	2,027 c	(4)	0,00 c	(6)	0,10 e	(8)
17	Resistant Standard trt.	(Blank) (Blank)	(Blank) (Blank)	0,000 f	(4)	0,192 de	(4)	0,00 c	(6)	0,00 e	(8)
18	Resistant Standard with low rates	(Blank) (Blank)	(Blank) (Blank)	0,000 f	(4)	0,000 e	(4)	0,00 c	(6)	0,00 e	(8)
19	Resistant alternatives	(Blank) (Blank)	(Blank) (Blank)	0,700 ef	(4)	1,619 c	(4)	0,26 c	(6)	0,02 e	(8)
20	Resistant PVO	(Blank) (Blank)	(Blank) (Blank)	0,985 def	(4)	0,683 de	(4)	0,13 c	(6)	0,20 e	(8)
LSD P=.05				1,2		0,8		3,8		3,1	
Standard Deviation				1,5		1,0		6,0		5,5	
CV				99,96		54,12		119,25		139,08	

Table 7: Description of the main input and output from the trials

Country	Comments
Denmark 20354-1	The cultivars Benchmark, Sheriff and Informer were used in this trial. Severe attack of YR developed in Benchmark following artificial inoculation. Only minor attack was seen in Sheriff. Good effect from fungicide treatments using both high input or reduced rates. No effect was seen from alternatives. DSS worked also ok. The cultivar mixture reduced YR attack significantly. High yields were measured in the trial and yield responses were highest in Benchmark. No yield increases from alternative treatments. The season was generally dry but as the trial was irrigated 3 times during the season the crop stand was good throughout the season.
Sweden 20354-2	The trial included the cultivars Memory, Julius and Informer. Moderate attack of YR in Memory, less in Julius and none in Informer. The cultivar mixture showed less severe infection compared to Julius. The two different intensities of treatments both showed a good result and so did the use of DSS. No effect was seen from alternatives. The trial yielded well, but the differences between the different varieties and treatments are quite small. Highest yield response for treatment tends to be in Memory. The season was dry during some periods, which caused some drought stress in parts of the trial.
Latvia 20354-3	Cultivars Kalmar, Julius and Informer were used in this trial. Artificial inoculations were made in May and June but no yellow rust was observed during the season. Attack of tan spot and powdery mildew developed with moderate attack. Yield levels were moderate and no clear increases were measured following treatments. In general the climate conditions were suitable for cereals.
Spain 20354-4	First symptoms of YR were detected at the beginning of April (no inoculation in this trial). During spring, the attack of yellow rust was severe in the susceptible (Camargo) and slow rust (Filon) cultivars. Minor attack was observed in the resistant cultivar although this variety was affected by septoria. The attack observed on the mixture was the mean of the incidence over the other 3 varieties. At a late stage there was a minor attack of leaf rust. Both full and reduced rate of fungicide programs provided full control of yellow rust. Similarly, the control under the thresholds program was also good. Alternative methods did not provide any efficacy on the control of YR but they showed a slight control on septoria. Mixtures provided only a small improvement with regards to the individual cultivars but proportional to the proportion of each cultivar on the mixture. So we did not see a mayor benefit from it. Yield responded to treatments and the yield of the plot was good around 9 T/ha. The climatic conditions during spring were favorable to yellow rust development with mild-high temperatures and high humidity. The general cropping conditions were good, therefore, wheat growth was also good.
Italia 20354-5	The trial was carried out on cultivars Tirex, Monastir and Iride. Attack of yellow rust only developed in Tirex and Monastir. Good control was achieve from both high and reduced input with fungicides. The alternative treatment provided insufficient control. The trial yielded ca. 5 T/ha and no clear yield responses were seen from any of the treatments.
Italia 20354-6	The trial was carried out on cultivars Monastir, Aureo and Line 467175. Even though the trial aimed at investigating stem rust – only minor attack was seen on SR susceptible Monastir (score 2, 1-9 scale). No clear data was obtained due to lack of diseases. The trial yielded ca. 4-5 T/ha and no clear yield responses were seen from any of the treatments.
UK 20354-7	The trials were carried out on cultivars JB Diego, KWS Zyatt and Crusoe. Significant attack of YR developed in both JB Diego and KWS Zyatt. Good effect from fungicide treatments using both high and low input. Low effects from alternatives were assessed. DSS worked also ok. Mixture reduced YR attack significantly. Slow ruster got severe attack of YR. Yield were high in the trial and responses from treatments ca. 1 T/ha for the best treatments.
Slovakia 20354-8	Artificial inoculation with yellow rust was carried out in April. The first attack of yellow rust was recorded in the cultivar Sunanka. The fungicides were applied according to the

	methodology. The infestation was low and the infection of YR spread slowly. The full and reduced rates of fungicide programs provided complete control of yellow rust. The best yield responses were measured from these variants. The efficacy of the alternative preparations was not significant. The fifth variant was treated only with Horizon at a dose of 0.5 l / ha, due to presence of yellow rust (in Sunanka) at the end of May. The yields were high with approximately 10 T/ha. Yield increases from the best treatments was ca. 1 T/ha.
Slovakia 20354-9	At the location Viglaš, a trial without yellow rust was carried out. April and May respectively, was very dry and cold and with night frosts, which was not conducive for development of yellow rust. Artificial inoculation with yellow rust was in April. We applied fungicides according to the methodology. The fifth variant was not treated. Yield levels varied between 8.5 and 9.7. Yield responses were 0.4-0.8 dt/ha
Germany 20354-10	The German trial was successfully sown, sprayed and assessed according to the protocol. Despite of artificial inoculation carried out twice with a spore mixture, yellow rust only developed moderately due to the dry conditions in March and April. In the cultivar Rumor and the mixture, attacked plants were found in the untreated control and the variant with alternative chemistry, but the severity was very low. The cultivar Informer proved completely resistant to yellow rust. Both the variant with low and high fungicide input led to full control of yellow rust in all cultivars. Severe attack of leaf rust developed at the end of the season. High incidence of LR was found in all cultivars in the untreated controls and in the variant with alternative chemistry. The leaf rust could only be controlled with the two fungicide variants. The yields were already high in the untreated controls. The highest yields were achieved by the cultivar Informer with 105 dt/ha in the variant with high fungicide input.
France 20354-11	Trial using susceptible variety Grapeli. Late and natural infection of YR developed in this cultivar. Good disease control was obtained using both high and reduced input using 4 fungicide treatments. Two applications were insufficient compared to four applications. No biocontrol solution was sufficiently effective on its own, but some very low activity appears to have been detected with *Bacillus subtilis.*
Switzerland.	The Swiss IPM trials profited from already ongoing IPM trials assessing recently released varieties with and without pesticides, as used in conventional agriculture systems in Switzerland. For the RustWatch purpose, an additional trial, with an alternative treatment (sulfur) as well as standard varieties and variety mixtures were added. Two IPM trials sites were sown in the canton of Jura and another in the region of Nyon. At the site in Jura, we found YR infections only in the susceptible border.

Table 8: Overview on disease attack and yield in the trials

				% attack of rust gs 75/77 untreated			
GPS	Cultivars		Yield hkg/ha untreated	YR Leaf 1	YR Leaf 2	LR Leaf 1	LR Leaf 2
Denmark Flakkebjerg 55,324177 N / 11,400075 E	Severe:	Benchmark	91,5	86,7	83,3	0	0
	Low:	Sheriff	114,6	1	1,5	0	0
	Resist:	Informer	107,4	0	0	0	0
	Mix:		108	26,7	26,7	0	0
Sweden Staffanstorp 55,669524 N / 13,180965 E	Severe:	Memory	104	15,67	9,33	0	0
	Low:	Julius	93,2	12,33	11,67	0	0
	Resist:	Informer	115,1	0	0	0	0
	Mix:		92,4	7,33	6,67	0	0
Latvia Stintes, Bauskas "56,4097 / 24,2009"	Severe:	Kalmar	59,5	0	0	0	0
	Low:	Julius	64,7	0	0	0	0
	Resist:	Informer	69,3	0	0	0	0
	Mix:		63,9	0	0	0	0
Spain Azpa "42,806053 N / 1,522250 W"	Severe:	Camargo	60,3	73,75	56,25	1,25	0,63
	Low:	Filon	70,4	26,88	42,5	1,25	5,63
	Resist:	Nudel	66,7	0	0	0	1,25
	Mix:		65,8	24,38	28,75	0,63	1,86
Italy Sicily "37 N / 14 E"	Severe:	Tirex	52,1	12	-	0	0
	Low:	Monastir	48,2	0	-	0	0
	Resist:	Iride	56,1	0	-	0	0
	Mix:		51,1	5	-	0	0
Italy Sicily "37 N / 14 E"	Severe:	Monastir	46,8	0	0	0	0
	Low:	Aureo	39	0	0	0	0
	Resist:	Line 467175	39,7	0	0	0	0
	Mix:		43,9	0	0	0	0
UK Cambridge "52,2 N / 0 ,09EW"	Severe:	JB Diego	65,3	3	13,33	0	0
	Low:	KWS Zyatt	65	5,67	12,33	0	0
	Resist:	Crusoe	67,7	0	0	0	0
	Mix:		67	0,03	2,7	0	0
Slovakia Borovce "48,577430 N / 17,728581 E"	Severe:	Sunanka	91,5	10,93	-	14,07	8,97
	Low:	Puqua	97,5	1,97	-	11,23	5,27
	Resist:	Jeldka	94,1	0,87	-	6,67	1,53
	Mix:		97,1	0,67	-	10,6	5,87
Slovakia Viglas "48,5419 N / 19,3203 E"	Severe:	Sunanka	88,2	0	0	10,01	10,48
	Low:	Puqua	85,8	0	0	1,53	2,17
	Resist:	Jeldka	87,4	0	0	1,32	1,33
	Mix:		90,8	0	0	1,85	3,74
Germany "Dahnsdorf 52.108494 N /12.636338 E	Severe:	Rumor	89,9	0,53	0,4	2,73	2,57
	Low:	Sheriff	92,8	0	0	1,23	1,73
	Resist:	Informer	98,1	0	0	0,8	0,77
	Mix:		100	0	0,13	0,83	1,07
France Rots	Severe:	Grapeli	76,5	81,67	100	0	0
	Low:	-	-	-	-	-	-

"49,2291 N / 0,4889 W"	Resist:	-	-	-	-	-	-
	Mix:		-	-	-	-	-
Switzerland Changins 46,398706 N / 6,232235 E	Severe:	CH Claro	67,2	54	-	8	-
	Low:	Diavel	77,2	1	-	0	-
	Resist:	Montalbano	81,1	2	-	33	-
	Mix: Montalbano+Baretta		72,1	1	-	25	-
Switzerland Courtételle "47,35148 N / 7,32401 E"	Severe:	CH Claro	79,4	0	0	0	0
	Low:	Diavel	69,9	0	0	0	0
	Resist:	Montalbano	87,7	0	0	0	0
	Mix: Montalbano+Baretta		82,4	0	0	0	0

Table 9: Information on treatments in the trials.

	Sowing time	Dates for treatments		Harvest date	Artificial inoculation?	Treatments in DSS
Denmark Flakkebjerg 55,324177 N / 11,400075 E	23-09-2019	H:	28/4 - 13/5 - 28/5 - 8/6	14-08-2020	Benchmark in April	28/5: 0,5 l/ha Elatus Era 8/6: 0,5 l/ha Folicur
		L:	28/4 - 13/5 - 28/5 - 8/6			
		A:	28/4 - 13/5 - 28/5 - 8/6			
		D:	28/5(ALL) - 8/6(SEV)			
Sweden Staffanstorp 55,669524 N / 13,180965 E	09-10-2019	H:	27/4 - 12/5 - 4/6 - 15/6	17-08-2020		4/6: 0,25 l/ha Elastus Era
		L:	27/4 - 12/5 - 4/6			
		A:	SEV 4/6 - SEV+LOW+MIX 15/6			
		D:	SEV 4/6			
Latvia Stintes, Bauskas "56,4097 / 24,2009"	06-11-2019	H:	4/5 22/5 5/6 15/6	14-08-2020	April	ingen
		L:	4/5 22/5 5/6 15/6			
		A:	4/5 22/5 5/6 15/6			
		D:	Not treated			
Spain Azpa "42,806053 N / 1,522250 W"	30-10-2019	H:	25/3 - 15/4 - 29/4 - 18/5	21-07-2020	No	20/4: 0,6 l/ha Comet 18/5: 0,75 l/ha Revycare
		L:	8/4 - 29/4 - 18/5			
		A:	8/4 - 15/4 - 29/4 - 18/5			
		D:	SEV+LOW+MIX: 20/4 - 18/5			
Italy Sicily 37,8447 / 13,5257	23-12 2019	H:	14/3 – 29/3 – 15/4 – 25/4	03-07-2020	No	17/3: 0,5 l/ha Prosaro, 18/4 & 26/4: 0,5 l/ha Folicur
		L:	14/3 – 29/3 – 15/4 – 25/4			
		A:	14/3 – 29/3 – 15/4 – 25/4			
		D:	17/03 - 26/4 (SEV), 18/04 (MIX)			
Italy Sicily 37,8447 / 13,5257	23-12 2019	H:	01/01 - 11/04 23/04 02/05	03-07-2020	No	04/05: 0,5 l/ha Folicur
		L:	01/01 - 11/04 23/04 02/05			
		A:	01/01 - 11/04 23/04 02/05			
		D:	04/05 (SEV)			
UK Cambridge "52,2 N / 0 ,09EW"	02-12-2019	H:	01/05 - 15/5 – 27/05 – 09/06	21-08-2020	No	15/5: 0.375 L/ha Prosaro 27/05: 0.25 L/ha Elatus Era 09/06: 0.25 L/ha Folicur
		L:	01/05 - 15/5 – 27/05 – 09/06			
		A:	01/05 - 15/5 – 27/05 – 09/06			
		D:	15/5 – 27/05 – 09/06			
Slovakia Borovce "48,577430 N / 17,728581 E"	15-10-2019	H:	15/4 – 4/5 – 22/5 – 3/6	31/7	April	3/6: 0,5 l/ha Horizon
		L:	15/4 – 4/5 – 22/5 – 3/6			
		A:	15/4 – 4/5 – 22/5 – 3/6			
		D:	3/6			
Slovakia Viglas "48,5419 N / 19,3203 E"	25-9-2020	H:	16/4 – 24/4 – 21/5 – 12/6	24/7	April	none
		L:	16/4 – 24/4 – 21/5 – 12/6			
		A:	16/4 – 24/4 – 21/5 – 12/6			
		D:				
Germany	22-10-2019	H:	7/5 - 18/5 - 29/5 - 8/6	31-07-2020	2/4 + 16/4	None

"Dahnsdorf 52.108494 N /12.636338 E "		L:	7/5- 18/5 - 29/5 - 8/6			
		A:	27/4 - 7/5 - 18/5 - 29/5			
		D:	No treatments			
France Rots "49,2291 N / 0,4889 W"	20-11-2019	H:	14/4 - 24/4 - 4/5 - 13/5	29-07-2020		14/04: 0,6 l/ha Comet Pro 24/04: 0.75 l/ha Amplitude 0,375 l/ha Comet Pro 04/05: 0,5 l/ha Elatus Era 13/05: 0.5 l/ha Balmora
		L:	14/4 - 24/4 - 4/5 - 13/5			
		A:	14/4 - 24/4 - 4/5 - 13/5			
		D:	14/4 - 24/4 - 4/5 - 13/5 (treated as H)			
Switzerland Changins 46,398706 N / 6,232235 E	17.10.2019	H:	20/3 - 21/4	14.07.2020	NO	-
		L:				
		A:	28/4 - 7/5 - 18/5 - 28/5			
		D:	-			
Switzerland Courtételle "47,35148 N / 7,32401 E"	14.10.2019	H:	19/5	22.07.2020	NO	-
		L:				
		A:	29/4 - 8/5 - 20/5 - 1/6			
		D:	-			

Tabel 10: summary of data with yellow rust

	untreated					full rate					half rate					alternative					dss				
	mixture	S	MR	R	avg of S,MR	mixture	S	MR	R	avg of S,M	mixture	S	MR	R	avg of S,M	mixture	S	MR	R	avg of S,M	mixture	S	MR	R	avg of S,MI
Denmark	27	83	2	0	28,3	0	0	0	0	0,0	0	0	0	0	0,0	25	90	1	0	30,3	0	0	0	0	0,0
Sweden	7	16	12	0	9,3	0	0	0	0	0,0	0	0	0	0	0,0	3	0	5	0	1,7	7	0	11	0	3,7
Latvia	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Spain	24	74	27	0	33,7	0	0	0	0	0,0	1	1	2	0	1,0	35	75	33	0	36,0	3	3	1	1	1,7
Italy 1 YR	5	12	0	0	4,0	0	0	0	0	0,0	0	0	0	0	0,0	2	2	0	0	0,7	1	2	0	0	0,7
Italy 2 LR	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Germany	0	0,5	0	0	0,2	0	0	0	0	0,0	0	0	0	0	0,0	0	0	0	0	0,0	0	0	0,1	0	0,0
UK	0	3	6	0	3,0	0	0	0	0	0,0	0	0	0	0	0,0	1	0	1	0	0,3	0	0	2	0	0,7
Slovakia 1	1	11	2	1	4,7	0	0	0	0	0,0	0	0	0	0	0,0	1	5	0	0	1,7	0	5	0	0	1,7
Slovakia 2	0	0	0	0	0,0	0	0	0	0	0,0	0	0	0	0	0,0	0	0	0	0	0,0	0	0	0	0	0,0
France	-	82	-	-	82,0	-	3	-	-	3,0	-	5	-	-	5,0	-	77	-	-	77,0	-	68	-	-	68,0
Switzerland	1	54	1	2	19,0	0	0	0	0	0,0	nd	nd	nd	nd	nd	0	46	8	2	18,7	-	-	-	-	-

Tabel 11: summary of data with yield data from trials

	untreated					full rate					half rate					alternative					dss				
	mixture	Severe R.	Low R.	Res. R	avg of 3	mixture	Severe R.	Low R.	Res. R	avg of 3	mixture	Severe R.	Low R.	Res. R	avg of 3	mixture	Severe R.	Low R.	Res. R	avg of 3	mixture	Severe R.	Low R.	Res. R	avg of 3
Denmark	108	91	115	107	104,3	114	119	118	113	116,7	115	121	119	113	117,7	111	95	117	110	107,3	114	112	117	110	113,0
Sweden	92	104	93	115	104,0	105	104	101	116	107,0	108	109	96	118	107,7	96	119	98	121	112,7	96	113	92	113	106,0
Latvia	64	60	65	69	64,7	69	54	52	63	56,3	62	61	64	68	64,3	59	67	62	69	66,0	57	68	59	66	64,3
Spain	66	60	70	68	66,0	94	92	97	88	92,3	92	92	95	90	92,3	68	53	70	75	66,0	87	83	96	67	82,0
Italy 1 YR	51	52	48	56	52,0	52	53	51	56	53,3	53	52	50	56	52,7	52	52	50	54	52,0	53	55	50	56	53,7
Italy 2 LR	44	47	39	40	42,0	46	51	42	42	45,0	46	52	42	42	45,3	43	50	38	38	42,0	44	49	40	39	42,7
Germany	100	89,91	92,76	98,11	93,6	102,34	96,76	101,01	105,45	101,1	95,48	99,09	101,17	105,14	101,8	91,74	95,14	95,06	104,31	98,2	97,38	90,53	90,97	99,65	93,7
UK	67	65	65	68	66,0	73	42	71	65	59,3	70	68	71	64	67,7	69	65	68	69	67,3	70	68	70	69	69,0
Slovakia 1	97	91	97	94	94,0	107	101	104	108	104,3	108	101	107	110	106,0	102	94	101	96	97,0	105	99	106	105	103,3
Slovakia 2	91	88	86	87	87,0	93	97	89	92	92,7	96	96	86	92	91,3	93	92	84	92	89,3	97	96	87	91	91,3
average of 8	78,0	74,8	77,1	80,2	77,4	85,5	81,0	82,6	84,8	82,8	84,5	85,1	83,1	85,8	84,7	78,5	78,2	78,3	82,8	79,8	82,0	83,4	80,8	81,6	81,9
France		77			77,0		97			97,0		98			98,0		79			79,0		81			81,0
Switzerland	72,1	67,2	77,2	81,1		80,1	72,7	77	89		nd	nd	nd	nd		74,6	68,5	75,4	78,1		nd	nd	nd	nd	