FINAL REPORT FOR ADOPT PROJECT # 20180492:

A FIELD-SCALE ASSESSMENT OF FUNGICIDE APPLICATION PRACTICES FOR FHB MANAGEMENT IN SPRING WHEAT

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Project Identification

1. **Project Title:** A field-scale assessment of fungicide application practices for FHB management in spring wheat
2. **Project Number:** 20180492
3. **Producer Group Sponsoring the Project:** IHARF
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6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project objectives:**

   The objective of this project is to demonstrate the effect of fungicide nozzle configuration and ground speed on spray quality and efficacy of *Fusarium* Head Blight (FHB) management in spring wheat on a field-scale.

8. **Project Rationale:**

   Producers make significant investments in crop protection products. Maximizing that investment involves 1) making the correct decision to spray, utilizing various risk management tools, 2) applying the product at optimal timing, and 3) ensuring effective coverage. Even while making the right decision to spray with optimal timing, efficacy may be lost if adequate coverage is not achieved, especially in the case of FHB since registered products provide only suppression, not control. Previous research and demonstration has explored several factors affecting spray coverage, including water volume, nozzle type and orientation/angle, droplet size, travel speed, and boom height. The following factors help ensure adequate spray coverage, specifically when targeting wheat heads for FHB management:

   1. Angled or double nozzles, asymmetric in particular – but only beneficial if droplet size is coarse enough to maintain spray angle;
   2. Adequate water volume – to achieve the same coverage with a coarser droplet size which helps maintain spray angle;
   3. Appropriate travel speed and pressure – to reduce turbulence and maintain adequate droplet size for angled/targeted spray;
   4. Optimal boom height – especially with finer sprays, to reduce turbulence and maintain angle of targeted spray.

   These factors interact with each other and with environmental conditions (wind speed and direction, evaporation potential) to affect spray coverage.

This study will demonstrate the effect of fungicide nozzle configuration and ground speed on spray quality and efficacy of FHB management in spring wheat on a field-scale. This project was conducted on a field scale to provide a better representation of influential factors that vary on a larger scale in producers' fields, such as crop stage, wind, turbulence caused by larger equipment, and potential for disease development. In addition, larger equipment provides the capacity for higher ground speeds which are difficult to achieve using small plot equipment.

In previous field trials, significant differences in visual disease ratings, yield, and grain quality were more likely to be observed in susceptible wheat varieties and in years/locations where disease prevalence was high. When growing season conditions are not conducive to *Fusarium* development, the assessment of spray quality using water sensitive paper can provide valuable quantitative data for evaluating the treatments. Therefore, water sensitive paper was utilized in this trial along with crop response variables to assess the effects of fungicide nozzle configuration and ground speed on spray quality and efficacy of FHB management in spring wheat on a field-scale.

Methodology and Results

9. Methodology:

The demonstration consisted of a field-scale trial with four treatments arranged in a randomized complete block design with four replicates. The trial was conducted near Indian Head, Saskatchewan (50.556 N, 103.606 W) during the 2019 growing season. Indian Head is situated in the thin-Black soil zone of southeast Saskatchewan. The treatments are listed in Table 1 and included different fungicide nozzle types (single or double flat-fan), nozzle sizes ("red" produces a finer spray than "grey"), and varying ground speeds. Treatment 3 demonstrates the recommended practice, to which the other treatments will be compared. Treatment 1 consists of the same nozzle size (grey), travel speed and pressure as treatment 3, and allows us to compare a single nozzle to a double nozzle. Treatment 2 consists of a finer nozzle size (red), with slower speed to maintain the recommended pressure. This treatment allows us to assess the effect of spray coarseness. Treatment 4 utilizes the same nozzle as treatment 3, and allows us to assess the effect of increased speed and pressure.

Table 1. Treatments evaluated in ADOPT - A field-scale assessment of fungicide application practices for FHB management in spring wheat at Indian Head in 2019.

Trt #	Nozzle	Travel Speed	Pressure
1	Single flat-fan (Turbo TeeJet, grey)	16 km/hr (10 mph)	275-310 KPa (40-45 psi)
2	Double flat-fan (Turbo TwinJet, red)	10 km/hr (6 mph)	275-310 KPa (40-45 psi)
3	Double flat-fan (Turbo TwinJet, grey)	16 km/hr (10 mph)	275-310 KPa (40-45 psi)
4	Double flat-fan (Turbo TwinJet, grey)	23 km/hr (14 mph)	620 KPa (90 psi)

The trial was seeded on May 8-9, 2019, with a Flexicoil air drill at 12" row spacing. The CWRS wheat variety CDC Landmark VB was seeded at 117 lbs/ac at a target depth of 1 – 1 ¼". CDC Landmark has a varietal rating of intermediate resistance to FHB. The seed treatment used was Insure Cereal FX4. The fertilizer used was 11-52-0 MAP side-banded at 76.9 lbs/ac and 28-0-0 UAN side-banded at 28.5 gal/ac for a total of 100-40-0-0 actual lbs/ac. Weeds were controlled on June 20 at the 4.5-5 leaf stage with Varro and OcTTain XL with ammonium sulfate 40% and 10.4 US gal/ac water volume.

Fungicide was not applied at flag-leaf timing. The fungicide application treatments were applied on July 12 within the time period when 15% to 80% of heads on the main stem were in flower. For all treatments, Caramba (metconazole) was applied at 400 mL/ha, the label rate for suppression of FHB. Water volume was non-limiting at 75 L/ac (20 US gal/ac) and kept consistent across treatments. The treatments were applied using a high clearance field sprayer (2008 Case SPX 3320) in 100'-wide strips, perpendicular to the crop rows, travelling eastward in replicates 1 and 3 and westward in replicates 2 and 4. Boom height was maintained at 20" above the wheat canopy.

Spray quality was assessed with AppliMax water sensitive paper (ATI Agritronics Inc.) that was placed in the field at the time of fungicide application. Six water sensitive paper cards were placed in each plot: 1) at canopy height, perpendicular to the sprayer's direction of travel, facing forward and backwards ("front" and "back"), 2) above the canopy, perpendicular to the sprayer's direction of travel, facing forward and backwards ("front" and "back"), and 3) above the canopy, parallel to the sprayer's direction of travel, facing North and South. The water sensitive paper samples were analysed using the DepositScan software, available as an online download from the USDA (https://www.ars.usda.gov/research/software/download/?softwareid=247). The DepositScan program assesses individual droplet sizes and total number of droplets, and calculates the droplet size distribution, percent coverage (%), droplet density (deposits cm^{-2}), and volume of deposition (µL cm^{-2}). Droplet size distribution is indicated by the parameters $D_{V.1}$, $D_{V.5}$, and $D_{V.9}$. Droplets with a diameter smaller than $D_{V.1}$, $D_{V.5}$, and $D_{V.9}$ (µm) compose 10%, 50% and 90% of the total liquid volume, respectively.

In-field FHB was assessed on August 6, when wheat was at the late milk to early dough stage. A total of 50 spikes in four locations per plot were rated for the percentage of the spike area that showed symptoms of disease. Severity and incidence of FHB was calculated for each plot individually. Plots were straight-combined at maturity on September 8 and yield was assessed separately for each plot. The area harvested from each plot was 1146' X 60' except for one plot that was 59' wide due to an unavoidable sprayer track. Grain samples were obtained separately for each plot at time of combining and sent to a third party for grading and level of *Fusarium* damaged kernels (FDK) and DON infection.

Data was analysed with the R statistical program, version 3.6.2, using the *lme4* package for fitting mixed-effects models, and the *lmerTest* package for tests of significance and estimation of least squares means. Response variables were log transformed or square root transformed to meet the assumption of normality. Mixed-effect models were fitted for each response variable individually. For water-sensitive paper response variables ($D_{V.1}$, $D_{V.5}$, $D_{V.9}$, % Coverage, Deposit density, and Deposition volume), Treatment, Location/Direction of paper, and their interaction were included as fixed effects, and Replicate as a random effect. Six data points were removed from this data set as they were extreme high values in all six of the response variables. For crop response variables (FHB Severity, FHB Incidence, FHB Index, Yield, FDK, and DON), Treatment was included as a fixed effect and Replicate as a random effect.

10. Results:

Growing season weather:

Mean monthly temperatures and precipitation amounts for Indian Head are listed in Table 2. Early season conditions were very dry, resulting in delayed crop development and variability in crop stages at the time of fungicide treatment application and throughout the growing season. Moisture conditions improved mid-season, and conditions were marginally favourable for FHB infection around the timing of crop anthesis. High moisture conditions persisted for the rest of the growing season, increasing the potential for late infection and disease development.

Table 2. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) normals for the 2019 growing seasons at Indian Head, Saskatchewan.

Year	May	June	July	August	Avg. / Total
		---------------------*Mean Temperature (°C)* --------------			
2019	8.9	15.7	17.4	15.8	14.5
Long-term	10.8	15.8	18.2	17.4	15.6
		-------------------------- *Precipitation (mm)* ----------------			
2019	13.3	50.4	53.1	96.0	148
Long-term	51.8	77.4	63.8	51.2	244

Conditions on date of fungicide application:

The fungicide application treatments were applied between 1:00 pm and 4:00 pm on July 12, 2019. Temperature was moderate, wind speed ranged between 9 and 15 km hr^{-1}, and wind direction was North-Northwest becoming West-Northwest during the time of application (Table 3).

Table 3. Hourly conditions from sunrise to late afternoon on July 12, 2019. Conditions during treatment application are shaded in grey.

Time	Temperature (°C)	Relative Humidity (%)	Wind Direction (deg)	Wind Speed (km/h)
5:00	9.9	92	290	10
6:00	11.4	93	290	8
7:00	14.7	89	330	9
8:00	16.7	81	330	8
9:00	18.4	66	340	8
10:00	19.6	65	340	8
11:00	21.1	58	310	8
12:00	22.4	52	310	14
13:00	23.1	53	330	10
14:00	23.4	49	290	9
15:00	22.5	53	260	15
16:00	22.4	53	280	15
17:00	21.9	62	230	3

The sprayer direction of travel was eastward for replicates 1 and 3, and westward for replicates 2 and 4. Wind direction likely influenced the deposition of spray on the water-sensitive paper cards placed towards (“front”) and away from (“back”) sprayer travel direction, however these effects were averaged out in the analysis. Wind effect on spray deposition in the north-south direction would not be averaged out as these are perpendicular to the sprayer travel direction.

Water-sensitive paper:

a. Droplet size:

Droplet size distribution is indicated by the variables $D_{V.1}$, $D_{V.5}$, and $D_{V.9}$. Droplets with a diameter smaller than $D_{V.1}$, $D_{V.5}$, and $D_{V.9}$ (µm) compose 10%, 50% and 90% of the total liquid volume, respectively. There was a significant overall effect of treatment on $D_{V.1}$ ($F_{3,90}$=3.49, P=0.019), $D_{V.5}$ ($F_{3,90}$=5.89, P=0.001), but not on $D_{V.9}$ ($F_{3,90}$=2.13, P=0.102). The interaction of treatment with location/direction was not significant at P<0.05 for $D_{V.1}$ ($F_{15,90}$=1.64, P=0.079), but it was significant for $D_{V.5}$ ($F_{15,90}$=2.09, P=0.017) and for $D_{V.9}$ ($F_{15,90}$=2.39, P=0.006). All three variables were log-transformed prior to analysis. Together, the three measures can be used to compare the range and variability of droplet sizes between treatments. However, the trends were nearly identical for the three variables, so we will examine $D_{V.5}$ individually as an estimate of average droplet size (Figure 1).

i. Treatment 1 vs Treatment 3, Single vs double nozzle:

Droplet size was similar between the two treatments overall. Droplet size did not differ significantly between location/direction for the double nozzle, while droplet size was less consistent among location/direction with the single nozzle relative to the double nozzle.

ii. Treatment 2 vs Treatment 3, Spray coarseness:

Droplet size was significantly finer overall with the red nozzle compared to the grey nozzle, as expected. Droplet size was consistent among location/direction with the grey nozzle. However, there were differences in droplet size between location/direction with the red nozzle, with the finest droplets being deposited on the back and south-facing cards.

iii. Treatment 3 vs Treatment 4, Speed and pressure:

Average droplet size did not differ significantly between treatments 3 and 4 overall. However, droplet size was much more variable between location/direction with the higher speed and pressure treatment compared to the “normal” speed and pressure. With higher speed and pressure, coarser droplets were deposited on the cards placed above the canopy and facing forwards and to the North, compared to the other cards.

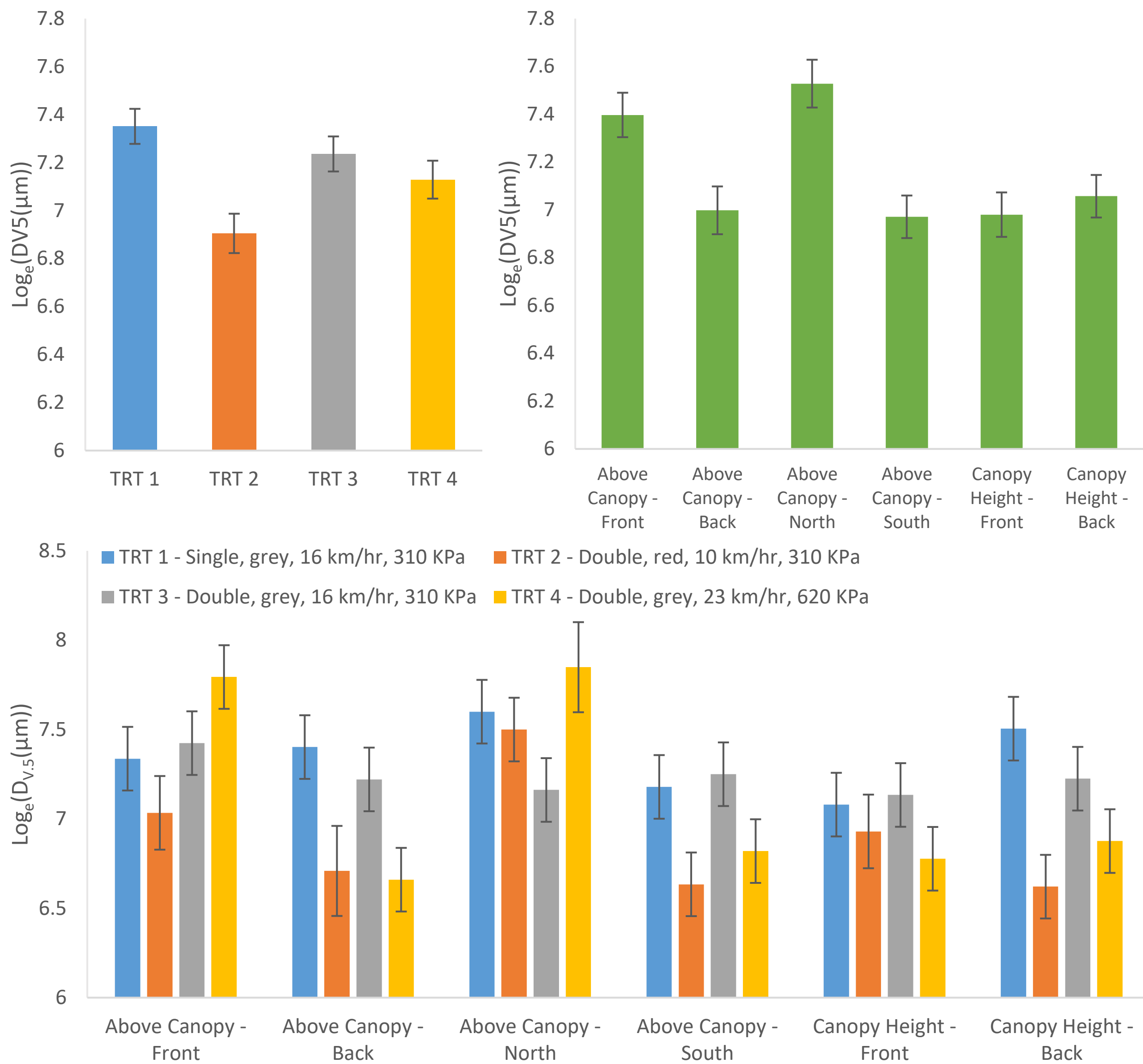

Figure 1. Least squares means for the effect of treatment and location/direction of water sensitive paper on droplet size. Error bars indicate the standard error. Log-transformed data is shown so that the standard errors can be used to compare treatment effects.

b. Percent coverage:

The effect of treatment on percent coverage was not significant overall ($F_{3,90}$=2.01, P=0.118), however there was a significant interaction between treatment and location/direction ($F_{15,90}$=2.47, P=0.004) (Figure 2). Percent coverage was square root transformed prior to analysis.

i. Treatment 1 vs Treatment 3, Single vs double nozzle:

Percent coverage did not differ significantly between the single and double nozzles overall, however coverage was much more consistent among location/direction with double than single nozzles. Coverage was lower on the front-facing cards with single nozzles compared to double nozzles.

ii. Treatment 2 vs Treatment 3, Spray coarseness:

Coverage appeared to be lower overall with the red nozzle compared to the grey nozzle, however the effect was not significant at P<0.1. Again, coverage was much more consistent among location/direction with the grey nozzle relative to the red nozzle. Coverage of red nozzles was lower than the grey nozzles on the cards placed above the canopy that were facing backwards and to the South.

iii. Treatment 3 vs Treatment 4, Speed and pressure:

Percent coverage did not differ significantly between the two treatments overall, however coverage was more variable with the higher speed and pressure. With higher speed and pressure, coverage was higher on the cards placed above the canopy and facing forwards and to the North, compared to the other cards.

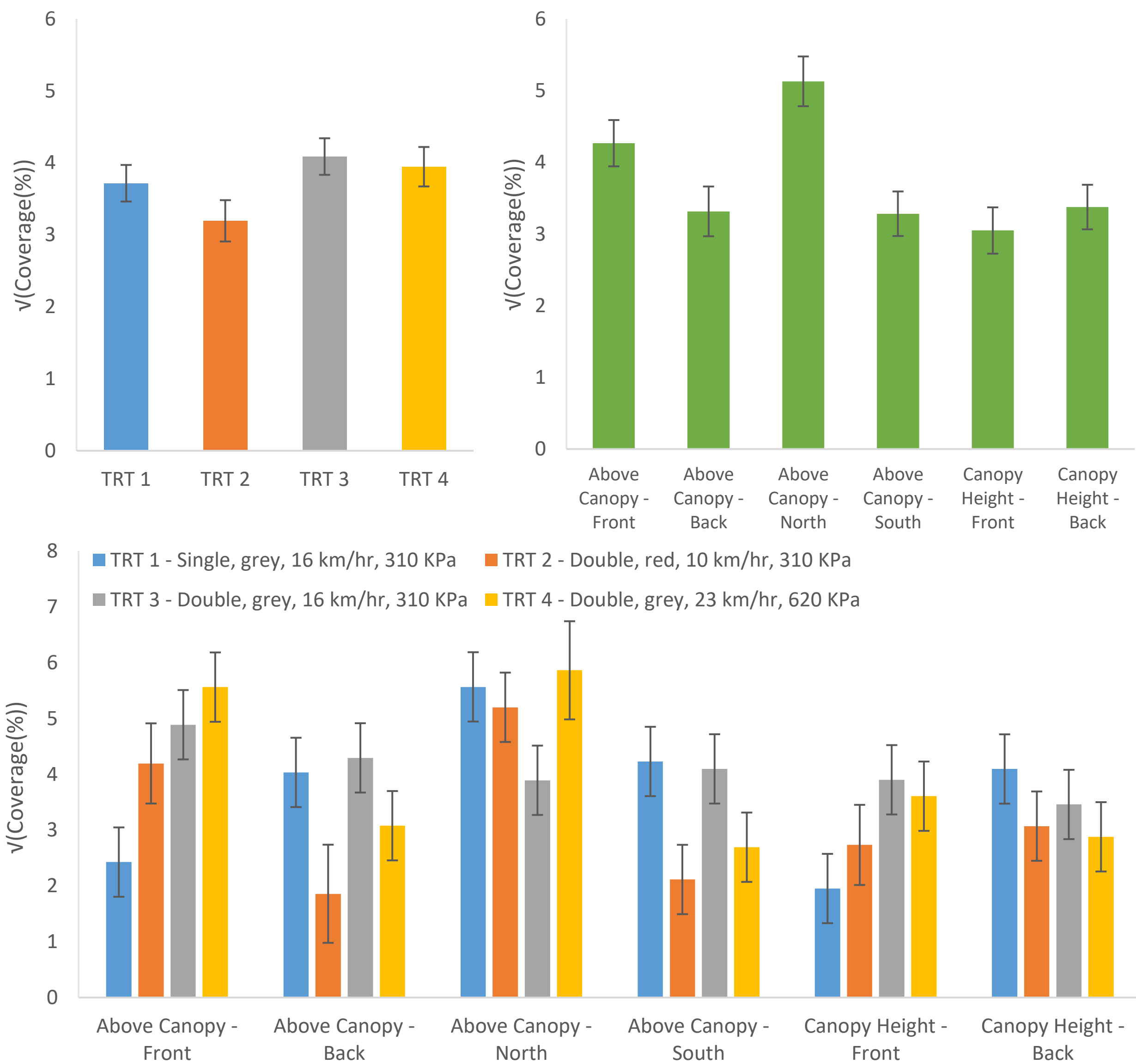

Figure 2. Least squares means for the effect of treatment and location/direction of water sensitive paper on percent coverage. Error bars indicate the standard error. Square root-transformed data is shown so that the standard errors can be used to compare treatment effects.

c. Deposit density:

The effect of treatment on deposit density was not significant overall ($F_{3,90}$=0.66, P=0.579), and the interaction between treatment and location/direction was also not significant ($F_{15,90}$=1.07, P=0.392) (Figure 3). Deposits cm^{-2} was square-root transformed prior to analysis. Standard errors were large for this variable, which limited the potential to detect significant treatment effects.

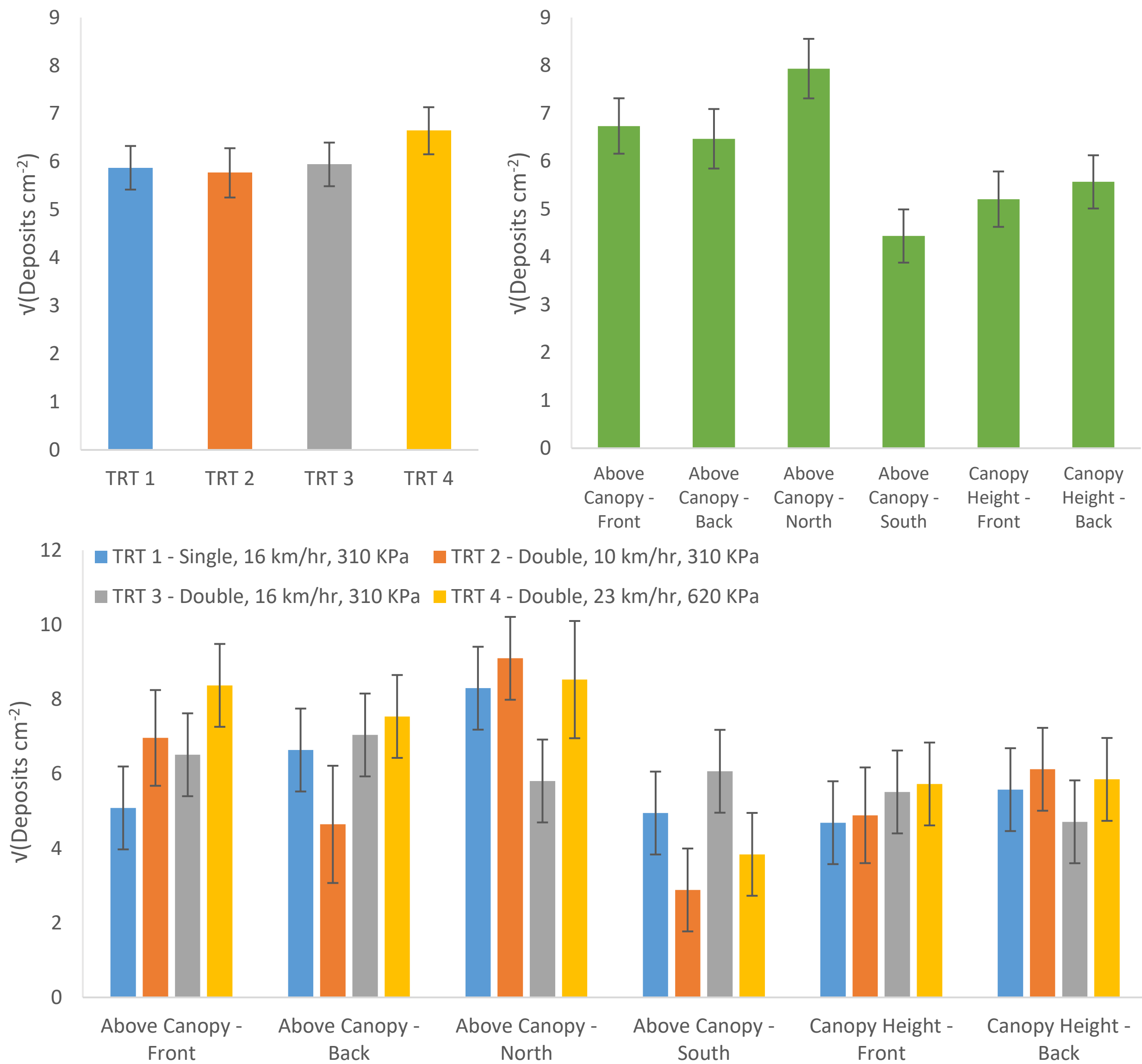

Figure 3. Least squares means for the effect of treatment and location/direction of water sensitive paper on deposits cm^{-2}. Error bars indicate the standard error. Square root-transformed data is shown so that the standard errors can be used to compare treatment effects.

d. Volume of deposition:

The effect of treatment on deposit volume was significant overall ($F_{3,90}$=3.40, P=0.021), and there was a significant interaction between treatment and location/direction ($F_{15,90}$=2.85, P=0.001) (Figure

4). Deposition was log-transformed prior to analysis. Note that there were no negative values in the raw data; these values would be positive when back-transformed.

i. *Treatment 1 vs Treatment 3, Single vs double nozzle:*

There does not appear to be a significant difference in overall deposit volume between single and double nozzles. Deposit volume was very consistent among location/direction for the double nozzle, while deposit volume was highly variable among location/direction with the single nozzle. Deposit volume was lower on the front-facing cards with single nozzles compared to double nozzles. Deposit volume was highest on the North-facing card with the single nozzle, and was higher on the backwards-facing than the forward-facing cards.

ii. *Treatment 2 vs Treatment 3, Spray coarseness:*

Deposit volume was significantly lower overall with the red nozzle compared to the grey nozzle. Deposition was fairly consistent among location/directions with the grey nozzle. For the red nozzle, deposit volume was highest on the cards placed above the canopy and facing forwards or towards the North, while the other four location/directions had lower deposit volume.

iii. *Treatment 3 vs Treatment 4, Speed and pressure:*

There was no significant difference in deposit volume between the two treatments overall. Deposit volume was very consistent among location/direction for the normal speed/pressure, while deposit volume was highly variable among location/direction at the higher speed/pressure. With higher speed and pressure, deposit volume was higher on the cards placed above the canopy and facing forwards and to the North, compared to the other cards.

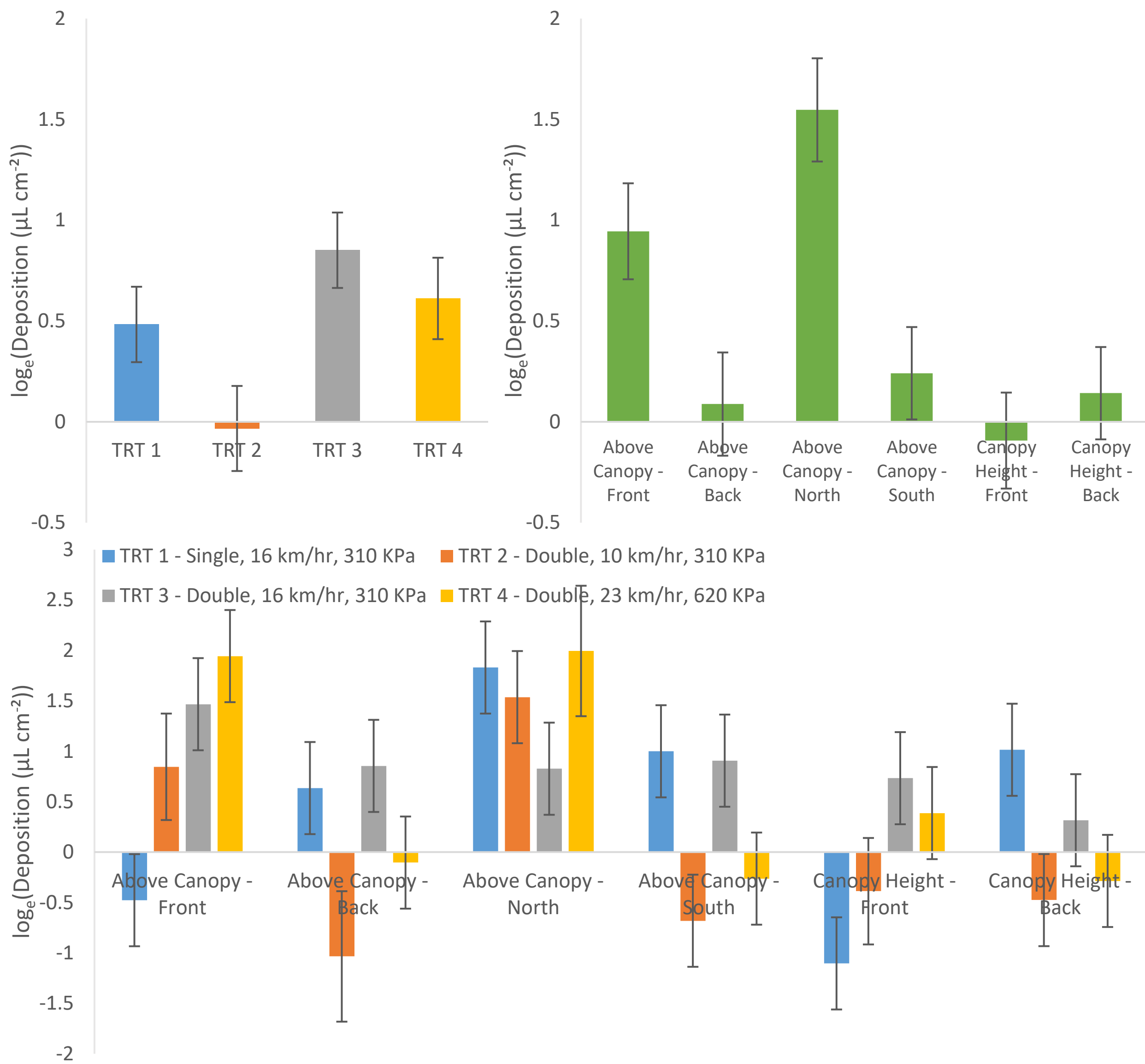

Figure 4. Least squares means for the effect of treatment and location/direction of water sensitive paper on deposition volume (µL cm^{-2}). Error bars indicate the standard error. Log-transformed data is shown so that the standard errors can be used to compare treatment effects.

The droplet size data suggests that single nozzles, finer spray, and higher speed/pressure all reduce the uniformity of droplet size deposition. A less uniform deposition of droplet sizes among location/direction indicates that the spray pattern and angle of spray was more vulnerable to turbulence and wind disturbance. Similar to the droplet size data, the percent coverage and volume of deposition results indicate that the treatments differed in the uniformity of coverage with more variability with each of the single nozzle, finer spray, and higher speed/pressure treatments. This would likely influence the efficacy of fungicide application, as even though the volume of deposition is adequate overall, variability in coverage would likely lead to inadequate doses of fungicide on sides of the wheat heads that have lower coverage.

Crop response variables:

There was a significant effect of treatment on FHB incidence ($F_{3,12}$=3.901, P=0.037), but not on any other crop response variables (Table 4). Least square means by treatment are shown in Figure 5.

a. FHB incidence

There was a significant increase of FHB incidence with treatment 4 (increased speed/pressure) compared to treatment 3 (recommended practice). There was also an apparent increase in FHB incidence with treatment 2 (finer nozzle size) when compared to treatment 3. Treatment 1 (single nozzle) did not differ in FHB incidence from treatment 3 (double nozzle).

b. FHB severity and index

There was no significant effect of treatment on FHB severity ($F_{3,12}$=0.486, P=0.698) or FHB index ($F_{3,12}$=1.682, P=0.224). However, treatment 4 (increased speed/pressure) appeared to have a higher FHB index than treatment 3 (recommended practice).

c. Grain quality and yield

There was no significant effect of treatment on DON levels ($F_{3,12}$=2.045, P=0.161), percent *Fusarium* damaged kernels ($F_{3,12}$=1.165, P=0.364) or yield ($F_{3,12}$=2.004, P=0.167). The *Fusarium* damaged kernel levels were less than 0.05% for all treatments and DON was less than 0.13 ppm for all treatments. The overall average yield across treatments was 4171 kg ha^{-1} (62 bu ac^{-1}).

Table 4. F-test results for the effect of fungicide application treatment on crop response variables.

	$F_{3,12}$	P
FHB Severity	0.486	0.698
FHB Incidence	3.901	**0.037**
FHB Index	1.682	0.224
Yield	2.004	0.167
FDK	1.165	0.364
DON	2.045	0.161

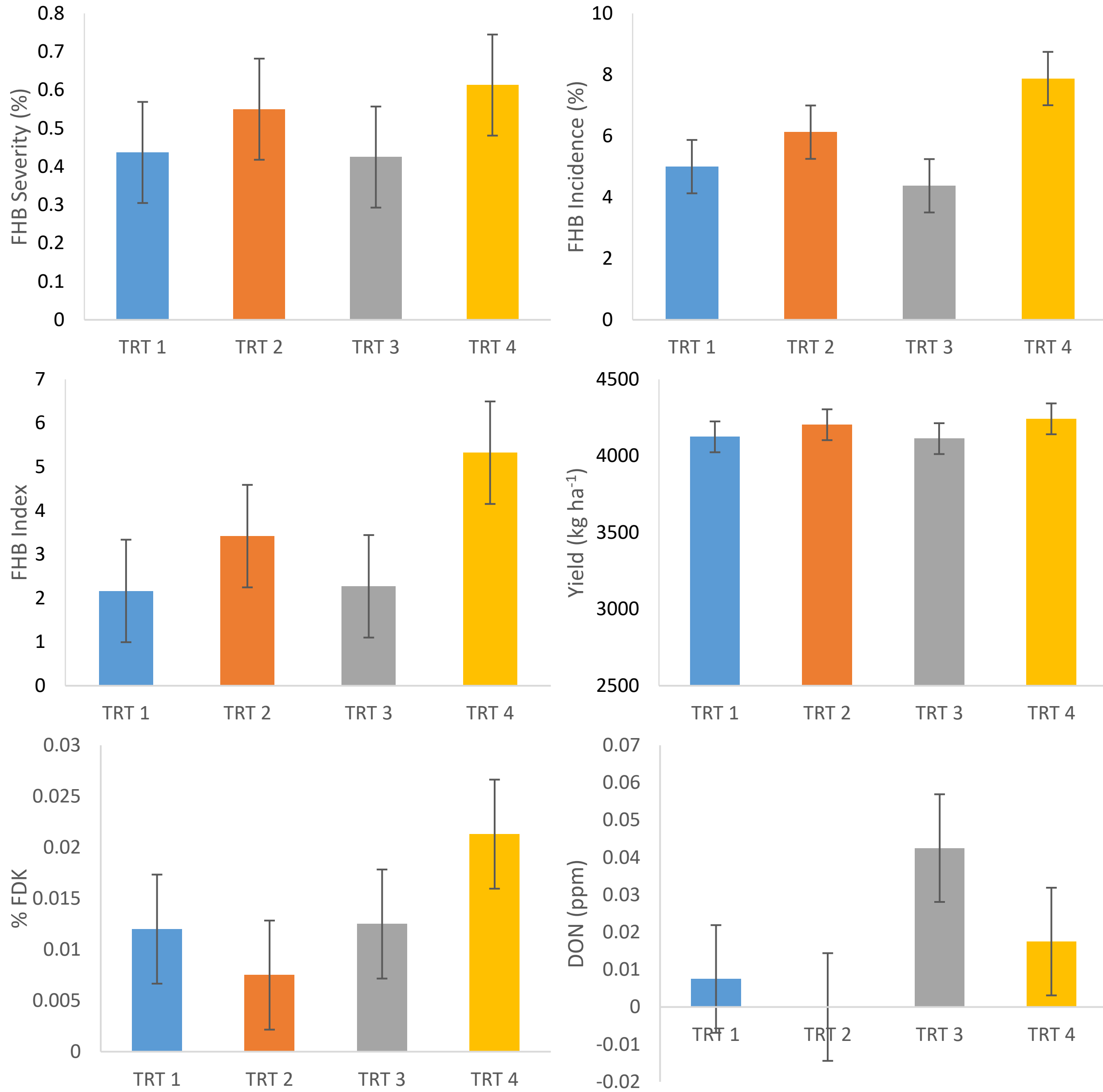

Figure 5. Least squares means of the effect of fungicide application treatment on *Fusarium* Head Blight (FHB) severity, FHB incidence, FHB index (severity x incidence), yield, % *Fusarium* damaged kernels (FDK), and level of DON infection. Error bars indicate the standard errors.

The environmental conditions of the 2019 growing season amounted to *Fusarium* being present in the field but at low levels. The grain yield, FHB Index and FHB Severity were not significantly affected by treatment and DON and %FDK were very low overall. This was not unexpected as the environmental conditions for FHB infection and development were only marginally favourable. Our varietal choice of CDC Landmark is rated as having intermediate resistance to *Fusarium* which may have also contributed to lower overall FHB prevalence. There was high crop stage variability throughout the field due to the early season dry followed by moisture mid-season. The variability in crop stage likely reduced the efficacy of the fungicide application overall throughout the whole trial.

The in-field FHB assessment data indicates that both the higher speed/pressure and the finer spray treatments increased FHB incidence. This suggests that both the higher speed/pressure and finer nozzle size treatments reduced the efficacy of the fungicide application enough to result in more incidence of *Fusarium* than the recommended nozzle size and ground speed. This increase in *Fusarium* incidence from higher speed/pressure and finer nozzle size can be explained by our results from the water sensitive paper data which indicated that single nozzles, finer spray and higher speed/pressure reduced uniformity of droplet size deposition and increased variability of coverage among location/direction. The reduced uniformity of droplet size indicates the angle of spray was more vulnerable to turbulence and wind disturbance and the more variable coverage may have led to inadequate doses of fungicide on sides of the wheat heads with lower coverage. However, the single nozzle treatment did not appear to reduce the efficacy of the fungicide application to the point where FHB incidence increased.

For extension purposes a poster will be made these compiling findings and displayed at various producer meetings in the future. The results of this project will also be summarized in the 2020 IHARF Annual Report and in a factsheet which will both be made available on the IHARF website (www.iharf.ca).

11. Conclusions and Recommendations

Conclusions

This trial demonstrates the importance of using an appropriate nozzle configuration and ground speed to enhance the spray quality and efficacy of a fungicide application against FHB in spring wheat. Relative to the expert-recommended double nozzle at appropriate speed and pressure, the use of single nozzles, finer spray and higher speed/pressure reduced uniformity of droplet size deposition which suggests the spray was more vulnerable to turbulence and wind disturbance. The single nozzle, finer spray and higher speed/pressure also had more variable coverage which potentially led to inadequate doses of fungicide on sides of the wheat heads that had lower coverage. Even in a year with low FHB prevalence overall, there was a significant increase in FHB incidence with the use of a finer nozzle size and higher speed/pressure relative to the recommended treatment.

This has implications from both an economic and a disease resistance management standpoint. Producers need to optimize the efficacy of their fungicide application to get the greatest return on their investment and also to prevent the application of a sub-lethal dose that may potentially accelerate the development of fungicide resistance. Using an appropriate nozzle configuration and ground speed/pressure in conjunction with adequate water volume and optimal boom height is essential to have adequate spray coverage and maximize the efficacy of a fungicide application.

Supporting Information

12. Acknowledgements

Funding was provided by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canadian Agricultural Partnership bi-lateral agreement between the federal government and the Saskatchewan Ministry of Agriculture, and will be acknowledged in any literature or oral presentations of the project results. Crop protection products were provided inkind by BASF. Tom Wolf (Agrimetrix Research & Training) and Troy Basaraba (Market Development Specialist – Bayer CropScience) were consulted in the development of this project. Chris Omoth (AAFC) and Jared Solomon (IHARF) provided technical guidance and support and conducted field operations. Logan Fahlman and Vlad Sheshnev provided assistance with data collection. IHARF has a strong working relationship and framework agreement with Agriculture & Agri-Food Canada which helps to make work like this a possibility.

13. Appendices

None.

<u>**Abstract**</u>

14. Abstract/Summary

A field-scale demonstration was established near Indian Head to demonstrate the effect of fungicide nozzle configuration and ground speed on spray quality and efficacy for *Fusarium* Head Blight (FHB) management in spring wheat. Four treatments were evaluated which varied in fungicide nozzle type, nozzle size and ground speed/pressure. Treatment 3 demonstrates the recommended practice (double flat-fan Turbo TwinJet, grey nozzle at 10 km/h and 275-310 KPa) which all other treatments were compared to. Treatment 1 utilized a single nozzle. Treatment 2 consisted of a finer nozzle size (red) at a slower speed to maintain the recommended pressure. Treatment 4 increased ground speed/pressure. Spray quality was assessed utilizing water sensitive paper and DepositScan software.

The use of single nozzles, finer spray and higher speed/pressure reduced uniformity of droplet size deposition and had more variable coverage relative to the recommended practice. The reduced uniformity of droplet size indicates the spray pattern and angle of spray were more vulnerable to turbulence and wind disturbance. The increased variability of coverage potentially led to inadequate doses of fungicide on sides of the wheat heads that had lower coverage. The grain yield, FHB severity and FHB index was not effected by treatment and DON and %FDK were very low overall. This was not unexpected as the environmental conditions for FHB infection and development were only marginally favourable. Even in a year with low FHB prevalence overall, there was a significant increase in FHB incidence with the use of a finer nozzle size and higher speed/pressure relative to the recommended treatment. This demonstrates that the appropriate nozzle configuration and ground speed/pressure is essential to maximize producer's investment in fungicide.

A poster will be made compiling findings and displayed at various producer meetings in the future. The results of this project will also be summarized in the 2020 IHARF Annual Report and in a factsheet both of which will be available on the IHARF website (www.iharf.ca).

<u>**Finances**</u>

15. Budget Report

Attached in separate spreadsheet file.