Reliability of Predicting Spring Wheat Yield with DSSAT Using Early Season Weather Data

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Introduction

A challenge for spring wheat producers is to obtain high yields while maintaining adequate grain protein content (GPC), as a negative relationship exists between yield and protein at a given level of fertility. In high yielding environments a late season foliar application of aqueous nitrogen (N) to enhance protein may be highly profitable as quality discounts result when protein levels do not reach a specified threshold. The Decision Support System for Agrotechnology Transfer (DSSAT) is a crop model that uses ecological and agronomic interactions to give an output of plant growth and yield components. The crop model may assist producers in making a decision on the economics of applying an additional N application to increase GPC.

Objectives

- Evaluate the ability of DSSAT in simulating hard red spring wheat yield at various points in the crop growth cycle.
- Use historic weather data in different approaches to forecast weather from a point in the crop growth cycle through the remainder of the growing season to simulate wheat growth.
- Determine if the profitability of a late season N application can be predicted based on forecasted yield from model simulations.

Materials & Methods

- Developed genetic coefficients for a regional spring wheat cultivar, Glenn, from variety trial data at North Dakota Research Extension Centers in 2005-2016 to calibrate DSSAT.
- Historic daily weather data and estimated Zadoks growth stages (ZGS 14, 45, 61) obtained from the North Dakota Agricultural Weather Network between 1991-2016 for five locations.
- Soil type, fertilizer and water inputs, planting date, and simulation criteria configured to simulate wheat growth for 2005-2016.
- Historic weather data configured to create different modeling approaches (distribution, historical average, and analogue) to forecast remaining season weather (Figure 1).
- Model performance was evaluated by analyzing the difference between simulated anthesis date and yield with measured weather data for the entire growing season, and the simulated anthesis date and yield with measured weather data up to each growth stage with the indicated modeling approach from that point through the remainder of the season. The smallest difference indicates the most accurate simulation.

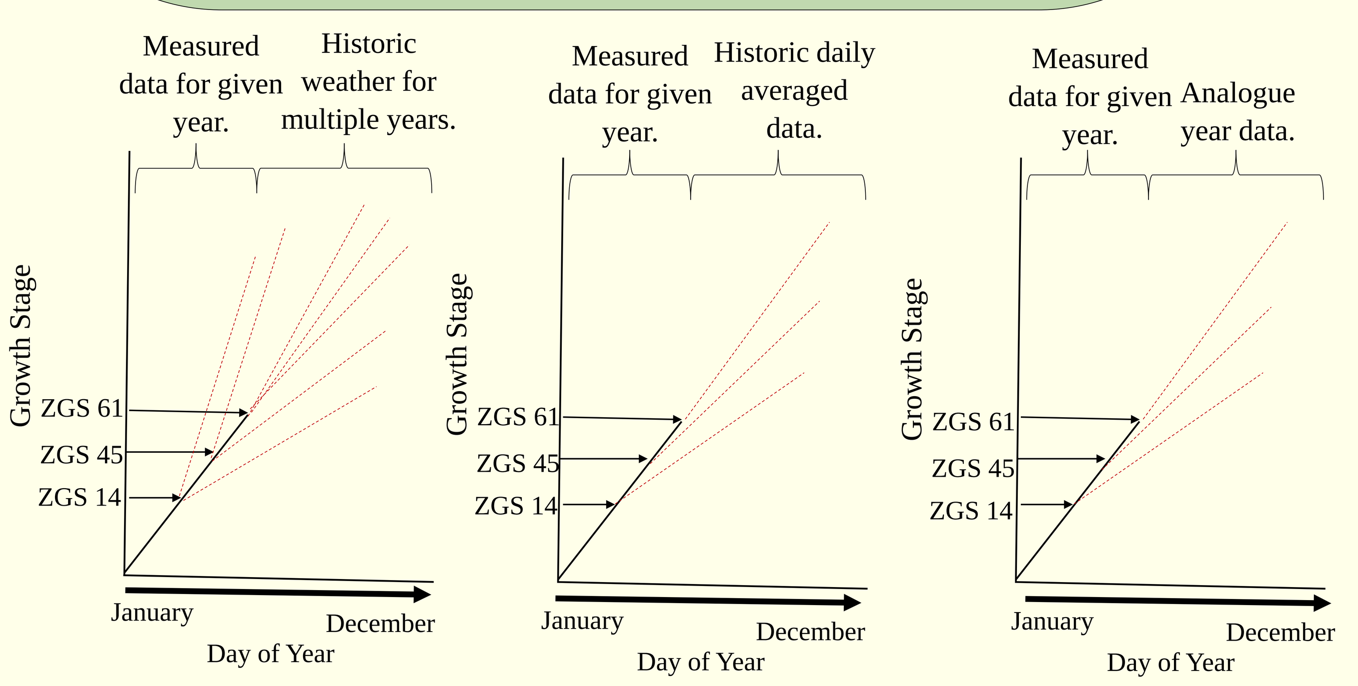


Figure 1. Formatting style of the different approaches (distribution, historical average, analogue) using historic weather data to forecast remaining season weather and model wheat growth.

Results

Table 1. Model calibration for anthesis date derived from regression in Statistical Analysis Software comparing estimated anthesis date from North Dakota Agricultural Weather Network and simulated anthesis date for five locations in ND.

Variable	Carrington	Hettinger	Langdon	Minot	Williston	Combined
RMSE†	1.9	1.4	5.8	2.5	5.9	2.2
CV ‡	2.8	2..0	9.2	4.1	9.1	3.2
r^2§	0.92***	0.96***	0.73***	0.66***	0.39**	0.70***

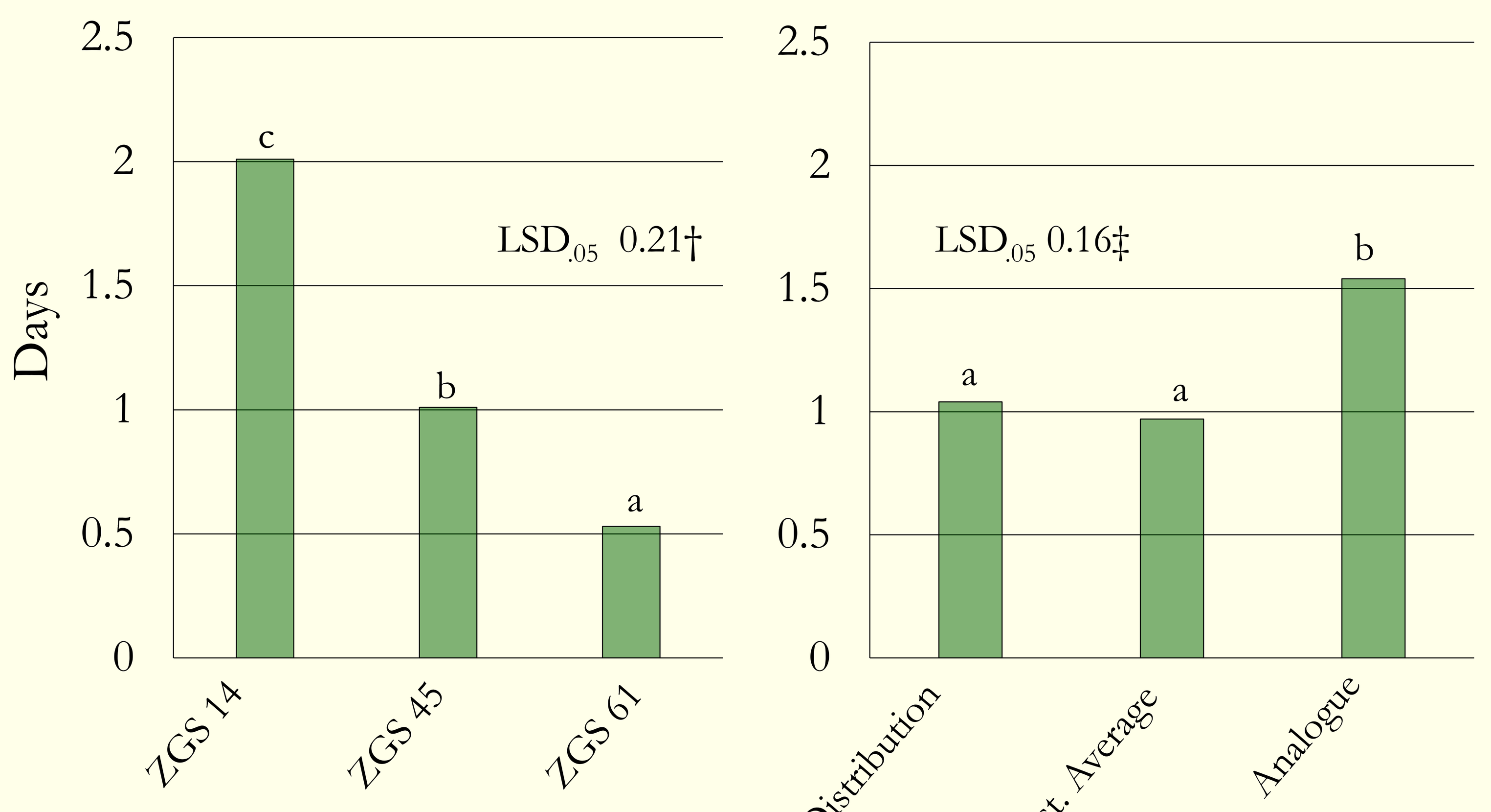
† Root mean square error
‡ Coefficient of variation
§ Coefficient of determination
*, **, *** Significant at (P≤0.10), (P≤0.05), and (P≤0.01) respectively

Table 2. Model calibration for grain yield derived from regression in Statistical Analysis Software comparing observed yield from North Dakota Research Extension Centers and simulated grain yield for five locations in ND.

Variable	Carrington	Hettinger	Langdon	Minot	Williston	Combined
RMSE†	705	806	617	733	548	814
C.V.‡	17.5	21.7	12.1	17.3	17.3	20.2
r^2§	0.52***	0.52**	0.16	0.50**	0.61***	0.46***

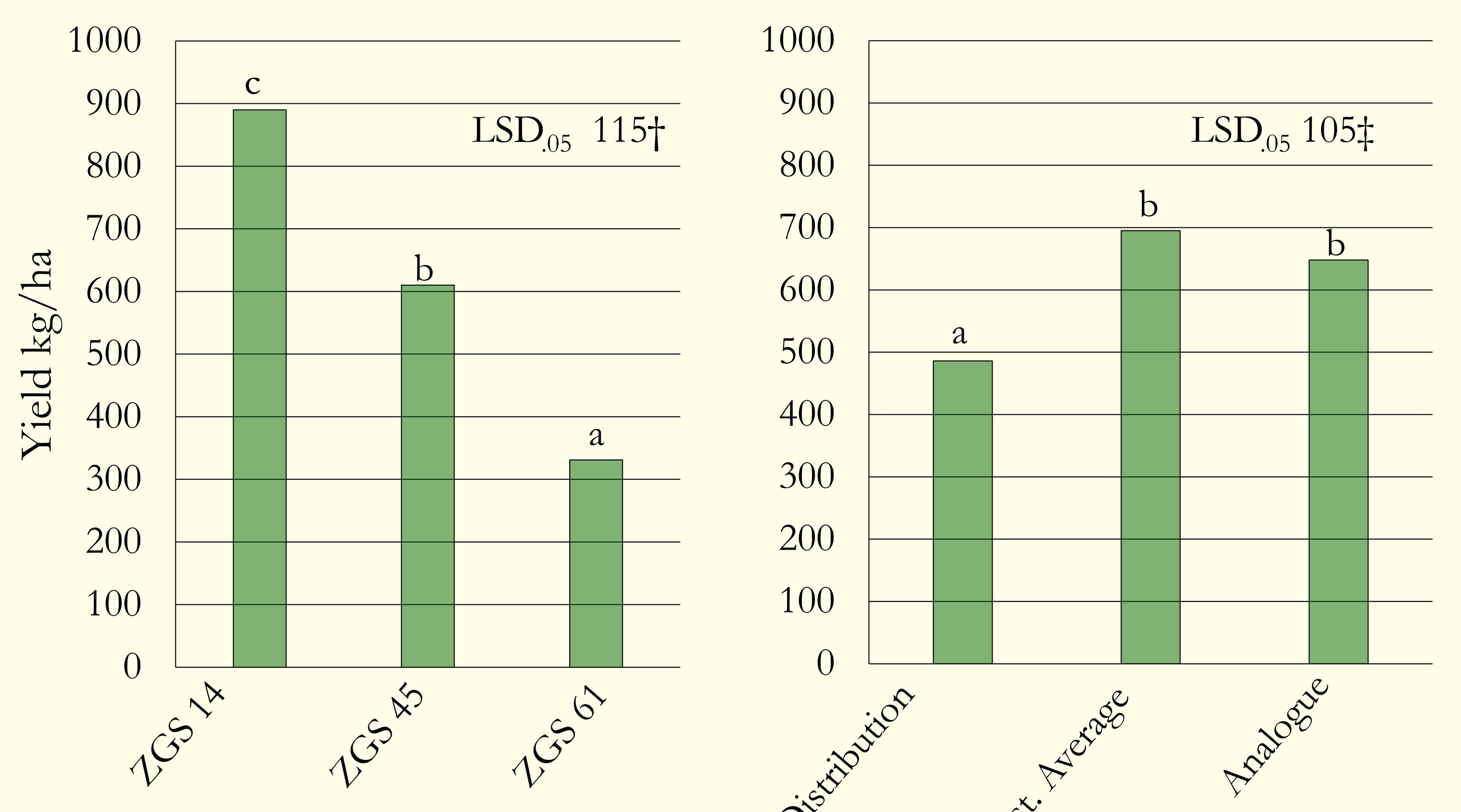
† Root mean square error
‡ Coefficient of variation
§ Coefficient of determination
*, **, *** Significant at (P≤0.10), (P≤0.05), and (P≤0.01) respectively

Figure 2. Difference of simulated anthesis date with full season weather data from simulated anthesis date with forecasted weather data from each growth stage using each modeling approach. Means derived from five locations in North Dakota.



† LSD for comparing ZGS.
‡ LSD for comparing simulation approach.
§ ZGS values not compared against simulation approach.

Figure 3. Difference of simulated yield with full season weather data from simulated yield with forecasted weather data from each growth stage using each modeling approach. Means derived from five locations in North Dakota.

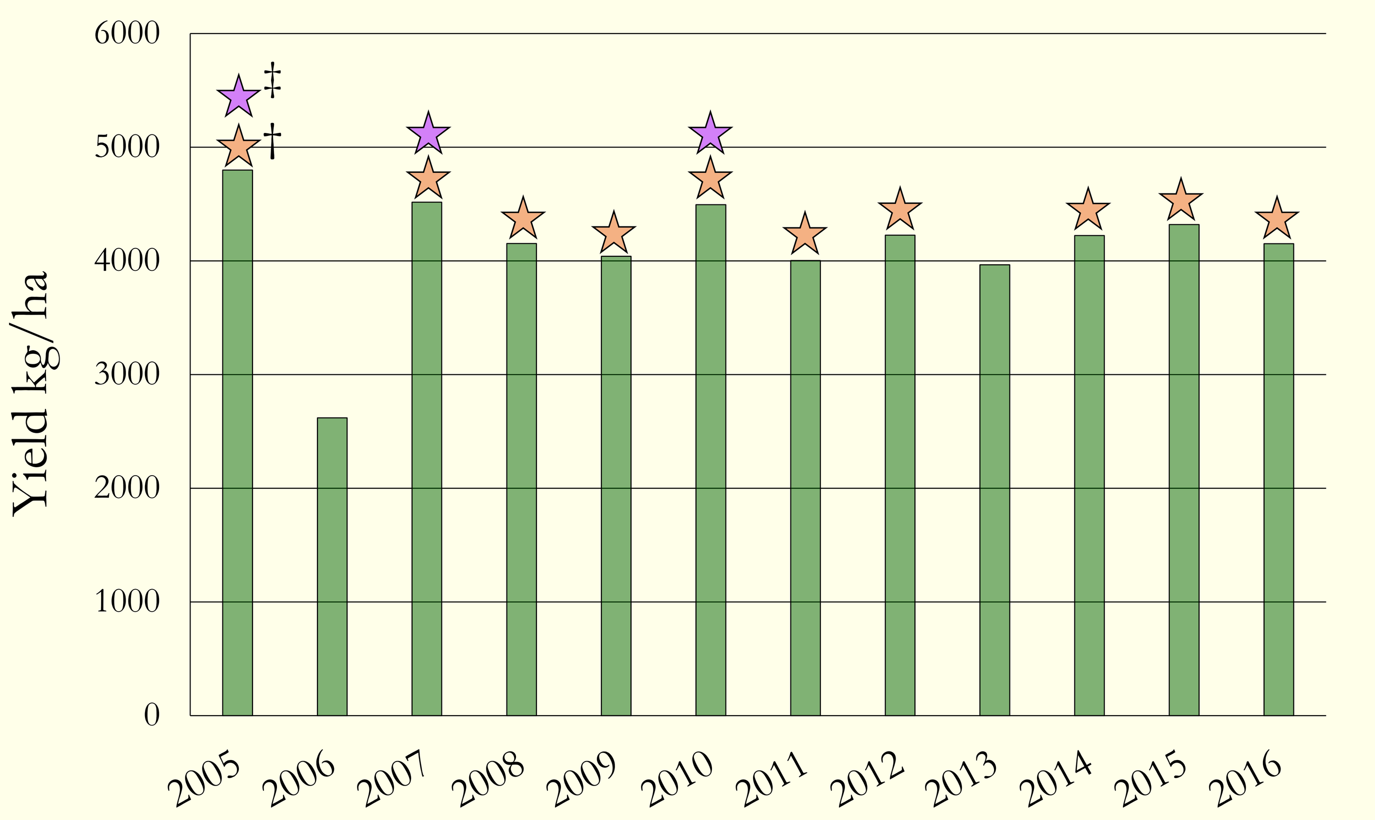


† LSD for comparing ZGS.
‡ LSD for comparing simulation approach.
§ ZGS values not compared against simulation approach.

Table 4. Economic return ($/ha) from a UAN application to increase protein, assuming a 0.5 point increase in protein and an application cost of $49.12/ha.

Premium/Discount	Yield Level (kg/ha)			
	2500	3250	4000	4500
$0.15	-$14.33	-$13.13	-$12.08	-$9.83
$0.30	-$8.78	-$6.38	-$4.28	$0.22
$0.45	-$3.23	$0.37	$3.52	$10.27
$0.60	$2.32	$7.12	$11.32	$20.32

Figure 4. Yield from crop model simulations with full season weather data derived with means from five locations across North Dakota.



† Indicates years with yields above 4000 kg/ha at a premium/discount of $0.45 where an additional nitrogen application will be profitable.
‡ Indicates years with yields above 4500 kg/ha at a premium/discount of $0.30 where an additional nitrogen application will be profitable.

Conclusion

The model was fairly accurate in simulating anthesis date and grain yield in North Dakota.

The relationship between observed anthesis date and grain yield to simulated anthesis date and grain yield with measured weather data (MWD) throughout the entire growing season was significant at p≤0.01 across all years and locations.

Grain yield was best simulated with the distribution approach that uses multiple years to forecast weather for the remainder of the season from a certain point in the crop growth cycle.

Grain yield was best simulated with MWD up to ZGS 61. Simulations with MWD up to ZGS 45 can be fairly accurate, but simulations were not accurate with MWD up to ZGS 14.

The cost of a late season N application must be equal to or less than the economic return from a premium or reduced discount in GPC. Assuming a 0.5% increase in GPC from this application, yield must equal 3250-4000 kg/ha with a premium/discount equal to or greater than $0.45 to realize a positive economic return.

Simulated yield from DSSAT indicated that an application of aqueous N would have been profitable in 10 out of 12 years between 2005-2016 at a premium/discount of $0.45 and in 3 out of 12 years at $0.30.

This study suggests that DSSAT has the ability to simulate yield using historic weather data to forecast the weather for the remainder of the season. This can be best accomplished using historic weather in the distribution approach from ZGS 45 or 61.

Acknowledgements

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